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TABLE OF CONTENTS

		PAGE
The North American Species of Clavaria, with Illustrations of the Type Specimens	E. A. Burt	1- 78
Monograph of the Isoetaceae	Norma E. Pfeiffer	79-232
A Monographic Study of Thelypodium and Its Immediate Allies	Edwin B. Payson	233-324
A New Hybrid Nymphaea	George H. Pring	325-332
A Bacterial Disease of Foxtail (Chaetochloa lutescens)	H. R. Rosen	333-402
The Toxic Property of Sulphur	H. C. Young	403-435
General Index to Volume IX		437-442

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THE NORTH AMERICAN SPECIES OF CLAVARIA WITH ILLUSTRATIONS OF THE TYPE SPECIMENS

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While little is known at present about the distribution of the various species of *Clavaria* in North America, nevertheless so many species of the genus have been described from North America that all students of this genus should find of permanent use the original descriptions of these species, their spore characters, and photographic illustrations of the type specimens. As further aid toward the study of local gatherings of species of *Clavaria* there are included also descriptions and photographs of the type illustrations, if in existence, of such European species as have been generally recognized as occurring in North America. I have appended a similar study of such South American and North Pacific Exploring Expedition species as were available for examination in the herbaria visited.

In order that specimens may be accumulated to show the geographic range of the species in North America, local study of the coral fungi in all parts of North America is greatly needed and notes on characters of fresh specimens, because some original, distinctive characters of the various species are not retained in the herbarium. For example, distinctive odor of garlic and an unusual taste have been given as determining characters in some recently described species and should be recorded for gatherings whenever noteworthy. Color of the fresh specimens is very important and should be noted, preferably in terms of a color standard such as Ridgway's, for there is the probability that the

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local gatherings may eventually be made available for showing distribution of the species to any one preparing a monograph of the genus.

Spore collections from the fresh specimens and record of the color of spores as a check in case of fading are of the highest importance for accurate determination at the time of gathering or for later study by a specialist. In many species the spores, as obtained from dried herbarium specimens, are unmistakably hyaline as seen with the microscope, while in many other species one cannot be quite sure from the microscopic examination alone whether the spores might not be appreciably colored in the mass, for the enormous magnification by the compound microscope dilutes the color of the spore to the same degree in the image seen.

Of the various methods of spore collection and preservation for the *Clavariaceae, Thelephoraceae, Hydnaceae, Polyporaceae,* and *Tremellaceae,* that on clean glass is preferable. Large cover glasses are sometimes used, but I cut with a glass cutter discarded negative plates or thin broken window panes into rectangles about 2 to 3 inches long and 1 inch wide. The falling spores adhere to the glass and are protected from dust by enclosure in close-fitting paper envelopes. In this condition they are preserved in the envelope or packet which holds the gathering from which the spore fall was saved. The color of these spores when first collected should be recorded, preferably on the envelope of the spore packet. In addition to showing the color of the spores, such mass collections consist of mature spores of normal size and form. Furthermore, a fructification which yields a copious spore fall is a mature specimen worth preservation and study and not one of the carelessly collected, worthless, sterile, immature things which clutter up herbaria and waste valuable time.

I have intentionally omitted synonymy of American species except in cases where later recognized by the authors themselves of species concerned. Before relegating species to synonymy, they should be studied from their author's point of view and an endeavor made to find characters separating them from related species. Good progress can be made by locating gatherings of Clavarias among the following species whenever in close agreement with any of them and noting cases in which the same specimen agrees exactly with two or more species, for it is well known that authors working independently of one another frequently describe the same species under different names, one

author emphasizing one set of characters and passing over others and another author emphasizing a different set of characters.

Key to the Species

§I. Fructifications branched ---------- 1
§II. Fructifications somewhat simple, cespitose at the base or fasciculate 28
§III. Fructifications somewhat simple, distinct at the base---------- 30

§I. RAMARIA. Branched species

C. rugosa and *C. Herveyi* sometimes have simple fructifications; *C. lavendula* is included in §II although somewhat branched and *C. sphaerospora* in §III although rarely branched.

1. Spores colored in the mass ---------- 2
1. Spores white in the mass, or at least hyaline in cases where mass color is unknown ---------- 14
2. Fructifications large, up to 10–15 cm. high ---------- 3
2. Fructifications medium-sized, 4–8 cm. high ---------- 6
2. Fructifications small, 1–3 cm. high ---------- 12
3. Spores about 3 times as long as broad ---------- 4
3. Spores about twice as long as broad ---------- 5
4. Branches red-tipped, spores 12–16×4–5 μ; striate ---------- *1. C. botrytis*
4. Branches red-tipped, spores 9–11×3–4 μ; rough ---------- *2. C. botrytoides, 3. C. conjuncta*
4. Whole fructification reddish to madder brown; stem elongated---- *4. C. holorubella*
4. Branches ochraceous, dichotomous, obtuse; stem short---------- *5. C. obtusissima*
5. Fructifications up to 15 cm. in diameter, pinkish buff, becoming violet and finally black where bruised ---------- *6. C. formosa*
5. Fructification ochraceous, becoming reddish where bruised ---------- *7. C. flava*
5. Fructification ochraceous, with a stout, pale trunk very dichotomously branched ---------- *8. C. aurea*
5. Fructifications whitish or creamy yellow; spores minutely rough, 8–10×4½–5 μ ---------- *9. C. densa*
5. Fructifications drying chamois-colored, with all branches anastomosing; spores mostly even, a few minutely rough ---------- *10. C. densissima*
5. Fructifications smoky ochraceous, drying drab to hair-brown; spores asperate ---------- *11. C. fumigata*
5. Fructifications reddish brown, drying Dresden brown to snuff-brown, radicated; spores intensely colored, strongly echinulate---------- *12. C. grandis*
6. Growing on the ground; spores intensely colored, strongly echinulate ---------- 7
6. Growing on the ground; spores pale-colored under the microscope--- 8
6. Growing on wood ---------- 11
7. Deep blue at first, becoming brownish olive in the herbarium; spores 10–13×6–8 μ---------- *13. C. cyanocephala*
7. Grayish brown at first, becoming Dresden brown in the herbarium; spores 11–15×6–8 μ---------- *14. C. spiculospora*
7. Dark brown at first, becoming tawny olive in the herbarium; spores 6–8×4–5 μ---------- *15. C. longicaulis*
8. Fructifications white, becoming yellowish or cream-colored with age, and sometimes red where bruised; spores 14×4 μ, even ---------- *16. C. xanthosperma*
8. Fructifications whitish, tardily acrid to taste, then bitter; spores 12–15×4–5 μ, even ---------- *17. C. albida*
8. Fructifications colored; spores more than 10 μ long---------- 9
8. Fructifications colored; spores not more than 10 μ long---------- 10

9. Pale yellow or whitish; stem short, soon branched; spores minutely uneven, 10–13×3½–4½ μ ---------- *18. C. secunda, 19. C. crassipes*
9. Pale drab with tips of branches olive-green, becoming everywhere fuscous in the herbarium; spores rough, 10–12×4–4½ μ ---------- *20. C. testaceoflava* var. *testaceoviridis*
10. Forming spherical tufts 3–5 cm. in diameter, turning green where bruised; in coniferous woods ---------- *21. C. abietina*
10. Fructifications cespitose from a subiculum, buff-yellow, dichotomously branched ---------- *22. C. flavula*
10. Dried stem 3 cm. long, 8 mm. in diameter, longitudinally furrowed, now clove-brown; spores minutely rough, 9–10×3½–4½ μ; in North Carolina ---------- *23. C. leucotephra*
10. Fructification yellow, with bruises turning brown, in the herbarium becoming tawny olive and discolored olive-brown; spores 7–9×3½–4 μ; in North Carolina ---------- *24. C. flavobrunnescens*
11. Fructifications tough, ochraceous, tinged with vinous, with root-like strands of white mycelium at base; taste bitter ---------- *25. C. stricta*
11. Fructifications as in *C. stricta* but acrid to taste; spores minutely rough, 6–7×4–4½ μ ---------- *26. C. acris*
11. Fructifications creamy yellow when young, becoming vinaceous cinnamon or reddish brown when mature, not becoming green where wounded; not bitter; spores 8–9×3–4 μ ---------- *27. C. tsugina*
11. Fructifications flesh-colored, then cinnamon; branches flattened; spores intensely colored, echinulate, 8×6 μ; in Dominica ---------- *28. C. cervicornis*
12. On pine log; spores 7½–9×4½–5 μ ---------- *29. C. pinicola*
12. On ground in Cuba; spores 13–15×9–10 μ ---------- *30. C. brunneola*
12. On ground in coniferous woods; spores less than 10 μ long ---------- 13
13. Bright ochraceous, rather tough but flaccid, not turning green when bruised ---------- *31. C. flaccida*
13. Yellowish, stem rather tough and drying olive-buff; branches drying drab; spores minutely rough, conglutinate in small groups in preparations ---------- *32. C. pusilla*
13. Pallid or almost whitish, drying pinkish buff, often rising from whitish mycelium whose strands bind the leaf mold; spores minutely rough, 7½–9×3–3½ μ; in spruce woods ---------- *33. C. circinans*
13. Drying pinkish buff, dichotomously branched, with white mycelial strands at base; spores 6×3 μ ---------- *34. C. flavuloides*
13. Pale ochraceous buff, fragrant, drying cream-buff; spores 4½–6×2½–3 μ ---------- *35. C. fragrantissima*
13. Tawny, with whitish mycelial strands, drying Saccardo's umber; spores rough or slightly subangular, 4–4½×2½–3 μ, conglutinate into small groups in preparations ---------- *36. C. myceliosa*
14. Fructifications white ---------- 15
14. Fructifications whitish to tan-color ---------- 20
14. Fructifications ochraceous or yellowish ---------- 21
14. Fructifications grayish ---------- 26
14. Fructifications lilac to violet ---------- 27
15. Spores globose or subglobose, less than 6 μ in diameter ---------- 16
15. Spores globose or subglobose, more than 6 μ in diameter ---------- 17
15. Spores broadly ovoid, even or minutely rough ---------- 18
15. Spores echinulate or tuberculate ---------- 19
16. Fructifications 5–12 cm. high, ivory-white to creamy white, dichotomously branched, base sometimes pink; spores even, 3–4½ μ in diameter ---------- *37. C. Kunzei*
16. Fructifications 8 cm. high, dichotomously branched, white to alutaceous, some branches rose-pink ---------- *38. C. arborea*
16. Fructifications 7½–12 cm. high, white or whitish, dichotomously branched; spores rough, 3½–4½ μ in diameter or 4½×3½ μ ---------- *39. C. subcaespitosa*
16. Fructifications 10 cm. high, white, drying cartridge-buff; stem and branches fibrillose-squamulose, tough; spores even, 5–6 μ in diameter; in Brazil. Belongs in *Lachnocladium* ---------- *108. C. cirrhata*
16. Fructifications 3–4 cm. high, white, soon turning brown or black;

probable spores 3–4×3 μ; in China ----------*104. C. decolor*
17. Fructifications 2–6 cm. high, with branches numerous, flattened upward and cristate; spores even, 9–12×6–8 μ----------*40. C. cristata*
17. Fructifications 3 cm. high, cespitose, drying with branches somewhat flattened, becoming bright antimony-yellow in the herbarium; spores 6–8×6 μ ----------*41. C. mutans*
17. Fructifications solitary or in small groups, simple or somewhat branched above, rugose, becoming antimony-yellow in the herbarium; spores even, 9–11×8–9 μ ----------*42. C. rugosa*
18. Fructifications very small, 2 cm. high, branched above, base of stem rufous; spores even, 4–6×3–4 μ----------*43. C. rufipes*
18. Fructifications 1–4 cm. high, dichotomously branched; spores becoming rough ----------*44. C. asperula, 45. C. asperulans*
19. Fructifications 3–4 cm. high, flour-white, soft, many branches flattened; spores tuberculate ----------*46. C. nodulosperma*
19. Fructification 4 cm. high, forked above five or six times, slender; spores echinulate, 3½–4×2½–3 μ; in Brazil. Probably a *Lachnocladium*------ ----------*109. C. dealbata*
20. Growing on wood, 3–10 cm. high, pallid, then alutaceous, somewhat reddish; branches and branchlets hollowed out into cup-shape at the apex and with margins of the cups proliferous-----*47. C. pyxidata*
20. Growing on wood but only 5 cm. high, branches and branchlets not hollowed out cup-shaped at the apex; spores 4×2–2½ μ---------- ----------*48. C. Petersii*
20. Growing on wood, pale yellow, then fawn-color, final branchlets encircled with crown of minute processes; spores 3–6×2–3 μ----- ----------*49. C. coronata*
20. Growing on the ground, 2–5 cm. high; spores subglobose, 9½×8–9 μ; not fleshy. A *Lachnocladium* ----------*99. C. ornatipes*
20. Growing under bark, alutaceous white, dichotomously branched, minutely subtomentose; not fleshy. Probably a *Lachnocladium.* ----------*100. C. subcorticalis*
20. Growing on the ground, 2–3 cm. high, divided from the base, branches compressed; basidia longitudinally septate. A *Tremellodendron* ----------*102. C. tenax*
21. Spores ovoid or cylindric ---------- 22
21. Spores globose or subglobose ---------- 24
22. Spores not even ---------- 23
22. Spores even, flexuous, 13–15×3½–4 μ; fructifications 2–4 cm. high; in pine woods ----------*50. C. pinophila*
23. Fructifications 5–7 cm. high, ochraceous; spores 4–5×2½–3 μ, with slender spines ----------*51. C. asterella*
23. Fructifications 5–10 cm. high; branches widely spreading, pale ochraceous; spores 11–13×4½ μ, distinctly rough ----------*52. C. divaricata*
24. Growing on wood, 15 cm. high, with stem 2–3 cm. thick; spores asperulate, 6×5 μ ----------*53. C. lentofragilis*
24. On leaves and twigs in Brazil, 1 cm. high, ochraceous; spores even, 4–5 μ in diameter ----------*105. C. delicia*
24. Growing on the ground; stem tough, tomentose, pale yellow; branches orange; spores 3–4 μ in diameter. A *Lachnocladium.* ----------*101. C. vestipes*
24. Growing on the ground; not tomentose ---------- 25
25. Fructifications apricot-yellow, 3–4 cm. high; spores even, 5–7 μ in diameter ----------*54. C. corniculata*
25. Fructifications pale yellow, 2–5 cm. high, tips of branches obtuse; spores even, 7–9×6–7 μ, mostly 7×6 μ ----------*55. C. Peckii*
25. Fructifications ochraceous yellow, 2–4 cm. high, tips of branches obtuse; spores even, 5–6×4½–5 μ ----------*56. C. muscoides* var. *obtusa*
25. Fructifications ochraceous yellow, 2½ cm. high, tips of branches obtuse; taste bitter; spores 5–6 μ in diameter----------*57. C. fellea*
25. Fructification golden yellow, with aspect of a dried specimen of *C. rugosa;* spores even, 8–9 μ in diameter----------*58. C. Herveyi*
26. Fructifications 3–5 cm. high; basidia with 2 sterigmata; spores

even, 7–10×6–8 μ ---------- *59. C. cinerea*
26. Fructifications 7 cm. high; basidia with 4 sterigmata; spores even, 5–6 μ in diameter ---------- *60. C. cinereoides*
27. Fructifications lilac, becoming yellowish in drying, 3–4 cm. high; spores even, 5–7 μ in diameter ---------- *61. C. amethystina*
27. Fructifications pale lilac, becoming tawny olive in drying, 2–4 cm. high; spores even, 6–7×5–6 μ ---------- *62. C. amethystinoides*
27. Fructifications 1–1½ cm. high, lavender, drying pinkish buff; spores 3×2 μ ---------- *63. C. exigua*

§II. SYNCORYNE. Species somewhat simple, cespitose at the base or fasciculate.

28. Fructifications bright yellow ---------- 29
28. Fructifications dingy greenish yellow or cinereous; spores asperate, 4½×3 μ ---------- *68. C. Macouni*
28. Fructifications drying drab; hair-like cystidia in the hymenium; in Porto Rico ---------- *69. C. pilosa*
28. Fructifications pale buff, rugulose; spores even, 10–10½×4½ μ ---------- *70. C. pallescens*
28. Fructifications clay color, blackening in drying; spores even, 6–7×3–3½ μ ---------- *71. C. nebulosa*
28. Fructifications lilac-pink, somewhat branched; spores even, 6×3 μ ---------- *72. C. lavendula*
28. Fructifications white; spores even, 3–5×3–4 μ ---------- *73. C. vermicularis*
29. Fructifications hollow, golden yellow verging to cinnabar at first, now between cinnamon drab and Rood's brown in the herbarium; spores hyaline, even, globose, 5–6 μ in diameter ---------- *64. C. aurantio-cinnabarina*
29. Fructifications often becoming hollow, clear canary yellow, odorless when fresh, taste bitter; spores at first yellow, then colorless, even, globose, 5–7 μ in diameter ---------- *65. C. fusiformis*
29. Fructifications probably solid, compressed, yellow alutaceous, now honey-yellow in the herbarium, 5–8 cm. long, tips obtuse; spores hyaline, even, globose, 5–6 μ in diameter ---------- *66. C. compressa*
29. Fructifications solid, compressed, canary-yellow at first, now yellow ocher, tips obtuse; spores hyaline, even, globose, 5–6 μ in diameter ---------- *67. C. platyclada*

§III. HOLOCORYNE. Species with clubs simple, distinct at the base, solitary or gregarious.

30. Fructifications white ---------- 31
30. Fructifications cinereous or mouse-colored ---------- *80. C. sphaerospora*
30. Fructifications pale rufous ---------- *81. C. filipes*
30. Fructifications yellow ---------- 34
30. Fructifications ochraceous to umber ---------- 38
31. Fructifications very small, usually less than 1 cm. high; on mosses, wood and stems of herbs ---------- 32
31. Fructifications more than 1 cm. high; growing on the ground ---------- 33
32. Fructifications 6 mm. high and pallid or white when growing, now 2 mm. long and pale pinkish-buff in the herbarium; spores hyaline, subglobose, 3–3½×3 μ; on moss ---------- *74. C. tenuis*
32. Fructifications up to 6 mm. high when growing, white, now pinkish buff in the herbarium; spores hyaline, even, 5–7×3–3½ μ; on moss in Cuba ---------- *75. C. misella*
32. Fructifications 1–2 cm. high, white or yellowish; on wood ---------- *76. C. mucida*
32. Fructifications 4 mm. high, white, not fleshy, difficult to crush under cover glass; on stems of *Epilobium*. A *Pistillaria* ---------- *103. C. Typhuloides*
33. Dull white to sordid yellow, becoming cinnamon brown in the herbarium; spores even, 3–4×2½–3 μ ---------- *77. C. biformis*
33. White, yellowish when dry, now russet in the herbarium; spores even,

7–9×4½–6 μ ---------- *78. C. subfalcata*

33. White, yellow when dry, now with hymenial portion honey-yellow and stem somewhat drab; odor of garlic; spores published as 6–9×5–7 μ ---------- *79. C. foetida*

34. On dead branches of *Carya;* 4 mm. high, pale yellow ---------- *82. C. spathulata*

34. Growing on the ground; spores about 2 or 3 times as long as broad ---------- 35

34. Growing on the ground; spores broadly ovoid or subglobose ---------- 36

35. Pale greenish yellow, 2–5 cm. high; taste like tallow; spores even, 10–11×5–6 μ ---------- *83. C. argillacea*

35. Yellowish or cream-colored, dried fructification 8 mm. high and pinkish buff; spores curved, 6–7×2½–3 μ ---------- *84. C. corynoides*

35. Pale yellow, 2½ cm. high, tip acute or acuminate; spores somewhat rugose, 7–8×3½ μ ---------- *85. C. gracillima*

35. Pinkish cinnamon, about 1 cm. high; spores even, 7–7½×2½–3 μ; on earth coated with bluish green algae ---------- *86. C. vernalis, C. clavata*

36. Fructifications 4–7½ cm. high, yellow to orange; spores subglobose, spiny, 5–6 μ in diameter ---------- *87. C. inaequalis*

36. About 1½ cm. high, citron-yellow; spores even, 4½–5×3 μ ---------- *88. C. citriceps*

36. About 2½ cm. high, pale golden yellow, somewhat pellucid; spores even, 4–4½×3–3½ μ ---------- *89. C. clara*

36. About 2½ cm. high, yellow to golden yellow; spores even, more than 5 μ long ---------- 37

37. Intense golden yellow, now cinnamon in the herbarium; spores probably hyaline, even, 4½–6×4–4½ μ; in Cuba ---------- *90. C. laeticolor*

37. Yellow, sometimes darker at apex, drying tawny to brick-red; spores hyaline, even, 6×4½ μ ---------- *91. C. pulchra*

37. Yellow, drying Prussian red, with apex acute; spores 6–7×4½–5 μ ---------- *92. C. flavella*

38. Fructifications large, 5–15 cm. high by 1–5 cm. thick, clavate, ochraceous buff; spores 9–11×4½–5 μ or larger ---------- *93. C. pistillaris*

38. Fructifications 3–7 cm. high, up to 1 cm. thick above, much narrowed downward, ochraceous; flesh solid; spores even, 10–14×4 μ ---------- *94. C. ligula*

38. Fructifications 5–20 cm. high, 2–5 mm. in diameter, becoming hollow; growing on buried wood ---------- *95. C. fistulosa*

38. Fructifications 2–4 cm. high, contorted; spores 14–18×6–9 μ; erumpent on alder branches ---------- *96. C. contorta*

38. Fructifications up to 5–8 cm. high, filiform, rusty to brownish, acrid to taste; spores 8–12×4–5 μ; on dead fallen leaves of frondose trees ---------- *97. C. juncea*

38. Fructifications 4–7 cm. high, 2–3 mm. in diameter, wood-brown; spores globose, 6–7 μ in diameter ---------- *98. C. asperulospora*

38. Fructifications less than 1 cm. high, pale umber, scabrous; spores probably subglobose, 1½–2 μ in diameter; in Brazil ---------- *107. C. scabra*

1. **Clavaria botrytis** Persoon, Comment. Clav. 42. 1797; Syn. Fung. 587. 1801; Myc. Eur. **1**: 161. 1822; Fries, Syst. Myc. **1**: 466. 1821; Hym. Eur. 667. 1874; Berkeley, Outl. Brit. Fung. 278. 1860; Sacc. Syll. Fung. **6**: 692. 1888; Peck, N. Y. State Mus. Rept. **32**: 57. 1879, and **48**: 211. *pl. 39. f. 5-7.* 1896; Morgan, Cincinnati Soc. Nat. Hist. Jour. **11**: 87. 1888; Cotton & Wakefield, Brit. Myc. Soc. Trans. **6**:171. 1919. Plate 1, fig. 1.

Illustrations: Schaeffer, Icones Fung. *pl. 176;* Holmskiold, Fungi Dan. **1**: *pl. 32;* Fries, Sverig. Atl. Svamp. *pl. 35;* Atkinson,

Mushrooms, *text f. 202;* Hard, Mushrooms, *text f. 386;* Peck, *loc. cit.* References to many other illustrations in Sacc. Syll. Fung. 19: 316.

Fructifications large, 10–12 cm. across and 7–12 cm. high, forming fleshy rounded masses with a short, stout base, densely branched above, white to buff, the tips of the branches reddish; smell slight, pleasant, taste pleasant; stem short, stout, white, tapering below; branching irregular, the primary branches few and stout (2–3 cm.), ultimate branches slender (2–3 mm.), more or less dichotomous; flesh solid, white; spores dull ochraceous in the mass, copious, entire in outline but with fine longitudinal or oblique striations often anastomosing, 12–16×4–5 μ.

On ground among leaves in woods.

Cotton and Wakefield add further that *C. botrytis* may always be recognized by its characteristic, striate spores.

I find the spores striate in the European specimen distributed as *C. botrytis* in Rabenhorst, Herb. Myc., 122, but none of the American specimens labelled *C. botrytis* in the exsiccati of Ravenel, Ellis & Everhart, and Shear have striate spores, and they differ further from *C. botrytis* as understood in Europe in having the spores minutely rough and only 10–12×3–4 μ, which are distinctive characters of *C. botrytoides.* Does *C. botrytis* occur in North America ?

2. **C. botrytoides** Peck, N. Y. State Mus. Bul. 94: 21, 49. *pl. 93. f. 5-7.* 1905; Sacc. Syll. Fung. 21: 426. 1913 Plate 1, fig. 2.

Type: in N. Y. State Mus. Herb.

"Stem small, short, divided near the base into branches which are repeatedly and irregularly branched, the ultimate branches short, crowded, blunt, usually terminating in two or more blunt teeth or protuberances, red or pink at the tips when young, soon fading and becoming concolorous, stem and branches solid; flesh white, taste mild; spores narrowly elliptic or oblong, rusty brown or subcinnamon, .0003–.0004 of an inch long, .00016–.0002 broad.

"The grapelike clavaria is very closely related to the red tipped clavaria and probably has been confused with it. It may be separated from that species by its thinner stem, the fading or evanescent character of the color of the ultimate branchlets and by its shorter and differently colored spores. The tips of the branches in mature or old plants are whitish like the branches

themselves, but often a few small branches may be found near the base of the plant which have red tips and are therefore presumably of later development. It is possible that these two clavarias have been confused in Europe for European mycologists do not agree in their description of the spore characters of the red tipped clavaria. Stevenson describes them as subhyaline, 12–15 μ long, 6 μ broad. Massee describes them as white, 8 μ long, 5 μ broad. In our plant the spores in mass have a rusty brownish or subcinnamon color when collected on white paper and they are 8–10 μ long, 4–5 μ broad.

"The plants are 2–4 inches tall and 1.5–3 inches broad. They grow in thin woods on rather poor soil and may be found in August and September. The edible qualities seem to me to be similar to those of the red tipped clavaria."

Ground in woods. Massachusetts, New York, South Carolina, and Idaho. July and August. Edible.

The fructifications of the type are now cream color, everywhere except the tips of the ultimate branches which are ocher red; spores only very slightly colored or nearly hyaline as seen with the microscope, becoming minutely rough, 9–11×3–4 μ, not striate. Peck's statement concerning the spores of *C. botrytis* presents the confusion in the characters of European species—frequently due to errors by Massee, as in this instance—which is a serious obstacle to progress in American mycology. Constructive work such as that by Cotton and Wakefield prepares the way for advances in other countries.

Specimens examined:

Exsiccati: Ell. & Ev., N. Am. Fungi, 2022, under the name *C. botrytis;* Ravenel, Fungi Car. **2**: 41, under the name *C. botrytis;* Shear, N. Y. Fungi, 57, under the name *C. botrytis.*

Massachusetts: Andover, *J. Blake,* comm. by P. L. Ricker.

New York: Alcove, *C. L. Shear,* in Shear, N. Y. Fungi, 57; Port Jefferson, *C. H. Peck,* type, in N. Y. State Mus. Herb.

South Carolina: Aiken, *H. W. Ravenel,* in Ell. & Ev., N. Am. Fungi, 2022, and in Ravenel, Fungi Car. **2**: 41.

Idaho: Mt. Baldy, *E. B. Payson, 2363* (in Mo. Bot. Gard. Herb., 57356).

3. **C. conjuncta** Peck, N. Y. State Mus. Bul. **105**: 16, 42-43. *pl. 102. f. 1-3.* 1906; Sacc. Syll. Fung. **21**: 426. 1913.

Plate 1, fig. 3.

Type: in N. Y. State Mus. Herb.

"Stems united at the base, forming tufts 3–5 inches tall and nearly as broad, fragile, solid, glabrous, white or whitish, divided above into numerous erect, crowded, solid branches which are whitish or pale buff, ultimate branchlets terminating in two or more blunt points which are pale pink, sometimes with a yellowish tinge; flesh white, taste mild; spores dingy yellow in a thin stratum, subochraceous in a thick one, oblong, .0004–.0005 of an inch long, .00016–.0002 broad.

"The conjoined clavaria is a large tufted and attractive species closely related to *Clavaria flava* on one hand and to *C. botrytoides* on the other. From the first it may be distinguished by the pinkish tips of the branchlets, from the second by their paler color and greater permanence and from both by the larger spores. It is similar to both in its fragile tender flesh and pleasant flavor. It grows among fallen leaves in woods. It was found at Bolton Landing, Warren Co. which yet remains its only known locality."

The fructifications comprising the type are now Isabella-colored except at tips of branches, which are light ochraceous-salmon; the branches have dried longitudinally rugose and channelled; spores slightly colored under the microscope, nearly hyaline, minutely rough, 9–11×3½–4 μ.

The tips of the branches are a little paler in their dried condition now than those of the type of *C. botrytoides*, but the two type specimens are not otherwise distinguishable in their present dried condition; perhaps field studies may show good, distinctive characters.

Specimens examined:

New York: Bolton Landing, *C. H. Peck*, type, in N. Y. State Mus. Herb.

4. **C. holorubella** Atkinson, Ann. Myc. 6: 57. 1908; Sacc. Syll. Fung. 21: 425 1912. Plate 2, fig. 6.

Type: in Cornell Univ. Herb.

"Plants 18 cm. high, spread of branching 12 cm. Trunk stout, 3 cm. in diameter, rooting, trunk with several stout branches which branch repeatedly, upper axils somewhat rounded. Entire plant reddish to madder brown, trunk deeper red than the branches; flesh reddish. Where spores are being developed surface covered with a whitish bloom. Basidia 4-spored. Spores

very pale yellow under the microscope, suboblong, slightly sigmoid in side view, smooth, 11–13×3–4.5 μ. Odor suggests that of water cress. - C. U. herb., No. 19979, and 19979a, Chillicothe, Ohio, rec'd Sept. 18, and Oct. 2, 1906, M. E. Hard."

The original specimen, No. 19979, is now tawny olive in the herbarium and discolored rather extensively sepia; the whitish bloom of the fresh specimens has become lost in drying, and also the odor of water cress; the spores are slightly colored in a microscopical preparation, flexuous, outline entire, surface obliquely striate, 12–13×4–4½ μ.

5. **C. obtusissima** Peck, N. Y. State Mus. Bul. **167**: 39. 1913.
Plate 4, fig. 18.

Type: in N. Y. State Mus. Herb.

"Much branching from a short thick whitish stem, the branches curving, dividing irregularly, enlarged above and divided into several blunt, wrinkled ends, longitudinally wrinkled, ochraceous, flesh white, taste mild; spores ochraceous in mass, oblong or subcylindric, 12–16×5–6 μ.

"Plant 10–12 cm. tall, 6–10 cm. broad.

"Woods of deciduous trees. West Roxbury, Mass. September. Miss Ann Hibbard."

The fructification grew on the ground, and is now between pinkish buff and cinnamon-buff, with ends of many of the branches, but not all, discolored to olive-brown, longitudinally wrinkled, and flattened in drying; spores somewhat colored, even, flexuous, 12–14×3½–4½ μ. I found no spores more than 4½ μ thick.

This species is noteworthy by the stout, loosely arranged main branches which are without subordinate lateral branches for nearly 2 centimeters and then dichotomously branched into terminal branches having thickened, obtuse ends.

6. **C. formosa** Persoon, Comment. Clav. 41. 1797; Icones et Descr. Fung. 11. *pl. 3. f. 5.* 1798; Syn. Fung. 585. 1801; Myc. Eur. **1**: 162. 1822; Fries, Syst. Myc. **1**: 466. 1821; Hym. Eur. 671. 1874; Peck, N. Y. State Mus. Rept. **32**: 36. 1879; Cotton & Wakefield, Brit. Myc. Soc. Trans. **6**: 173. 1919.
Plate 2, fig. 7.

Illustrations: Persoon, Icones et Descr. Fung. *pl. 3. f. 5;* McIlvane, Am. Fungi, *pl. 139, f. 3.*

Fructifications large, about 15 cm. in diameter, gregarious, much branched, very fragile, color pinkish buff, pale at first but deeper later, the tips of the branches yellowish or very slightly tinged with pink, every part turning violet and finally black when bruised; taste slight, smell none; stem white at first, then deep pinkish buff, rooting base absent; branches erect, cylindric or flattened, elongated, distinctly grooved, 1 cm. thick below, 2 mm. above, apices blunt; flesh white, solid; a few latex hyphae present; basidia with 4 sterigmata; spores pale colored, ochraceous in the mass, minutely granular, nearly even, 9–11 $\times 5\,\mu$.

On the ground under beech trees.

Cotton and Wakefield add further: "*C. formosa* is a large, very fragile plant, differing from *C. botrytis* in the fact that the apices of the branches are yellowish, or at most slightly tinged pinkish, and in the granular, not striate spores. It is distinguished from *C. flava* and *C. aurea* by the pinkish buff color, which is somewhat like that of *C. stricta*."

C. formosa has been reported from New England and North Carolina by Berkeley & Curtis and by Atkinson, from New York by Peck, from New Jersey and Pennsylvania by McIlvane, and from Ohio by Morgan and by Hard, but in no instance has it been recorded that the specimens met the European test of turning violet and finally black when bruised.

7. C. flava Schaeffer, Icones Fung. *pl. 175.* 1763; Persoon, Comment. Clav. 43. 1797; Syn. Fung. 586. 1801; Myc. Eur. **1**: 162. 1822; Fries, Syst. Myc. **1**: 467. 1821; Hym. Eur. 666. 1874; Sacc. Syll. Fung. **6**: 692. 1888; Peck, N. Y. State Mus. Rept. **24**: 81. 1872, and **48**: 210. *pl. 39. f. 1–4.* 1896; Cotton & Wakefield, Brit. Myc. Soc. Trans. **6**: 169. 1919.

Plate 4, fig. 19.

Illustrations: Schaeffer, *loc, cit.;* Peck, *loc. cit.*

Fructifications large, branched, 8–13 cm. high, fleshy, fragile, ochraceous, becoming paler on drying and reddish when bruised; smell pleasant, taste mild; stem thick, white or tinged reddish; branching irregular or irregularly dichotomous, repeated, axils acute, not flattened; branches slender, cylindrical, erect, solid, smooth or slightly wrinkled, apices blunt or pointed; basidia with 4 sterigmata; spores pale ochraceous in the mass, almost hyaline by transmitted light, narrowly elliptical, incurved at the base,

walls slightly granular, 11–14×4–5 μ.

Cotton and Wakefield add further: "It is found in both coniferous and frondose woods (especially beech) where it occurs either isolated or in groups as a pale fragile plant with a marked tendency to become reddish at the base or when bruised. The color is pale ochraceous, paler and yellower than in *C. formosa*, which has a tendency to become dull pink.

"The correct identity of the three species, *C. flava* Pers., *C. formosa* Pers., and *C. aurea* Fr. is a very perplexing problem and one which owing to the scarcity of authentic material and the meagerness of the original descriptions it is perhaps impossible to solve. There can be little doubt that the plant here referred to as *C. flava* is the same as that described by Persoon under the same name, and in this view we have the support of Maire (loc. cit.). In this country it has been usually referred to as *C. aurea*, an error which arose largely as a result of Fries' statement that *C. aurea* differed from *C. flava* in its ochraceous spores. This was incorrect, as in all the species of this section the spores are colored, though in some species more so than in others."

C. flava has been reported from all parts of the United States by mycologists who have followed Fries' statement as to color of spores for distinguishing between this species and *C. aurea* and have left no record of color changes where the specimens were bruised.

8. **C. aurea** Schaeffer, Icones Fung. *pl. 285, 287.* 1763; Fries, Epicr. 574. 1838; Hym. Eur. 670. 1874; Sacc. Syll. Fung. **6**: 699. 1888; Morgan, Cincinnati Soc. Nat. Hist. Jour. **11**: 88. 1888; Cotton & Wakefield, Brit. Myc. Soc. Trans. **6**: 170. 1919.

Plate 3, fig. 12.

Trunk thick, elastic, pale, divided into stout, tense and straight, very dichotomously branched, round, obtuse, somewhat toothed, yellow branches.

On the ground in pine woods.

C. aurea has been reported from various parts of the United States on the basis of the foregoing too brief description. Future gatherings which seem referable here by close agreement with this description and with the reproduction of the original illustration and which disagree with characters of the other better-known species here described, should be carefully studied, preserved, and their characters fully described. In the several series of Euro-

pean exsiccati in the Missouri Botanical Garden Herbarium there are no specimens labelled *C. aurea.*

Concerning *C. aurea* in Great Britain, Cotton and Wakefield state: "With regard to *C. aurea* it is difficult to dogmatise as to its identity. The English specimens so named consist as stated above for the most part of *C. flava,* but a few which as far as can be seen from herbarium material only differ in possessing shorter spores may be distinct also in other characters, and these may possibly represent the *C. aurea* of Fries. Until the Swedish species of *Clavaria* have been critically worked out it is advisable not to attempt to describe the plant or list the species for Britain."

9. C. densa Peck, N. Y. State Mus. Rept. **41**: 79. 1888; Sacc. Syll. Fung. **9**: 249. 1891. Plate 2, fig. 9.

Type: in N. Y. State Mus. Herb.

"Tufts 2 to 4 in. high, nearly as broad, whitish or creamy-yellow, branching from the base; branches very numerous, nearly parallel, crowded, terete, somewhat rugose when dry, the tips dentate, concolorous; spores slightly colored, subelliptical, .0003 to .0004 in. long, .0002 to .00034 broad.

" Ground in woods. Selkirk. August."

The type specimen has no single prominent trunk but instead a cluster of equal trunks start from the ground and are closely crowded together; the color is now between cream-buff and pinkish buff throughout; spores slightly colored, minutely rough, 8–10×4½–5 μ.

10. C. densissima Peck, Torr. Bot. Club Bul. **30**: 98. 1903; Sacc. Syll. Fung. **17**: 193. 1905. Plate 1, fig. 5.

Type: in N. Y. State Mus. Herb.

"Tufts 7–10 cm. high, nearly as broad, very dense, closely and intricately branched from the base, the branches solid, white within, often compressed, very crowded, repeatedly and irregularly branching, sometimes anastomosing, pale ochraceous when dry, the ultimate branches more or less compressed and dilated, terminating in two or more blunt or pointed whitish tips; spores naviculoid, often uninucleate, 8–10 μ long, 4–5 μ broad; mycelium whitish.

"Much-decayed vegetable matter in mixed woods. Greenville, Michigan. October. B. O. Longyear. Near *C. densa* and *C.*

condensata, but from the latter it differs in color and from the former in its more compact mode of growth, compressed branches, more narrow spores, and in having the tips of the branches differing in color from the branches themselves. The branches appear glabrous to the naked eye, but under a lens they have a minutely velvety appearance. This indicates a relationship to the genus *Lachnocladium,* but it is not clearly shown by the dried specimens that the texture is coriaceous."

The type fructification is now everywhere chamois colored; it has the cluster of main stems and all branches except the small terminal branchlets anastomosing and grown together at points of contact from the base upward in a highly characteristic manner; spores ochraceous where occurring as dust in axils of the branches, somewhat colored under the microscope, minutely rough, 9×4 μ. The fructification grew from the ground but partially inclosed a piece of wood which was in its way, and shows transversely across the lower part of the fructification in the illustration.

11. C. fumigata Peck, N. Y. State Mus. Rept. **31**: 38. 1879; Sacc. Syll. Fung. **6**: 711. 1888. Plate 2, fig. 10.

Type: in N. Y. State Mus. Herb.

"Stem short, thick, branching from near the base, whitish; branches numerous, forming a dense mass, smoky-ochraceous, sometimes tinged with lilac; tips obtuse; spores .0003′–.0005′ long.

"Ground in woods. Ticonderoga. Aug.

"The tufts are 4′–5′ high and remarkable for their smoky or dingy color."

The type fructifications are now drab to hair-brown; spores copious, colored, distinctly rough, 9–10×4–4½ μ. *C. fumigata* is a species well marked by its form, size, color, and spores.

12. C. grandis Peck, Torr. Bot. Club Bul. **29**: 73. 1902; Sacc. Syll. Fung. **17**: 195. 1905. Plate 3, fig. 13.

Type: in N. Y. State Mus. Herb.

"Stem stout, distinct, radicating, divided above into numerous long, erect or slightly diverging branches which are repeatedly branched, solid but very fragile, glabrous, reddish-brown with white tips at first, becoming somewhat pulverulent and ferruginous brown with concolorous tips when old, somewhat fragrant;

spores ferruginous, broadly elliptic or subglobose, distinctly verrucose, 10–12 μ long, 6–8 μ broad.

"Plant 12–20 cm. high, nearly as broad above; stem 2–2.5 cm. thick.

"Thin woods under *Smilax* bushes. Maryland. September. F. J. Braendle.

" According to Mr. Braendle this large *Clavaria* is edible when prepared as pickles and put up in spiced vinegar."

Fructification growing on the ground, radicated, now Dresden-brown to snuff-brown, discolored darker in a few places; basidia 2-spored; spores intensely colored, strongly echinulate, flattened on one side, the body of the spore 10–12×6–7 μ. In the N. Y. State Mus. Herbarium there are more recent collections referred by Peck to *C. grandis* which have fructifications of the same form but much smaller and with similar, characteristic spores. These additional specimens were collected in Massachusetts by S. Davis, and in Vaughn, New York, by S. H. Burnham.

C. grandis belongs in the group of which the other American species are *C. cyanocephala*, *C. spiculospora*, and *C. cervicornis*. The species of this group are alike in their intensely colored and strongly echinulate, beaked spores, but differ from one another in dimensions of spores and fructifications and in form and color of the latter. According to recent studies, which are cited in connection with *C. cyanocephala* Berk. & Curtis, *C. aeruginosa* Pat., *C. Zippelii* Lév., and *Thelephora acanthacea* Lév. of the East Indies are species of the same group and all need comparison with one another.

13. **C. cyanocephala** Berk. & Curtis, Linn. Soc. Bot. Jour. **10**:338. 1868; Sacc. Syll. Fung. **6**: 711. 1888. Plate 3, fig. 14.

Lachnocladium cyanocephala (Berk. & Curtis) Patouillard, Jour. de Bot. **3**: 35. 1889.—An *Clavaria aeruginosa* Patouillard, Soc. Myc. Fr. Bul. **14**: 189. 1898 ? See von Höhnel & Litschauer, K. Akad. Wiss. Wien Sitzungsber. **119**[1]: 394. 1910. —An *C. Zippelii* Léveillé, Ann. Sci. Nat. Bot. III. **2**: 215. 1844? See von Höhnel & Litschauer, *loc. cit.*—An *Thelephora acanthacea* Léveillé, Ann. Sci. Nat. Bot. III. **5**: 147. 1846 ? See von Höhnel & Litschauer, K. Akad. Wiss. Wien Sitzungsber. **122**: 278. 1913.

Type: from Cuba, *C. Wright, 261,* in Curtis Herb.

"Stipite subdiviso, ramis ramulisque furcatis sursum intense

caeruleis, apicibus breviter bifidis obtusis subfastigiatis.

"Among leaves in thick woods. June. Hab. Bonin Isles. About 3 inches high."

The specimen from Cuba, upon which the original description was based, is now brownish olive; spores coarsely echinulate, intensely colored, the spore body 10–13×6–8 μ.

14. **C. spiculospora** Atkinson, Ann. Myc. **7**: 368. 1909; Sacc. Syll. Fung. **21**: 426. 1912, as *C. spiculosperma*. Plate 2, fig. 11.

Type: an authentic specimen which was compared with the type is in Burt Herb. The type could not be found in Cornell Univ. Herb. although a photograph of it is present there.

"Plant about 6 cm. high, stem 5 cm. long, 0,8–1 cm. in diameter. Several short branches clustered at the top. Branches subdichotomous to subtrichotomous. Terminal branchlets coarsely dentate to subpyxidate, some of them resembling molars. Stem grayish brown, whitish below, the whitish part stained with pink or pale purple. Branches grayish brown, tips abruptly white. Spores reddish brown, a brick color, long, obovate and curved at the smaller end, covered with sharply pointed spicules, spicules being nearly 2 μ long. Spores 11–13×6,5–7,5 μ.—C. U. herb., No. 22638, ground, mixed woods, Chapel Hill, N. C., W. C. Coker, Oct. 08."

The authentic specimen in Burt Herb. was communicated to me by Professor Atkinson in 1911 together with his type for study and with inquiry whether known to me already as a *Thelephora*. This specimen seemed to me to be the same species as his type, but larger, more branched above; it is now buckthorn-brown; basidia 2-spored; spores intensely colored, strongly echinulate, with body 11–15×6–8 μ.

When collected again, the characters as to color of the fresh specimens should be compared with those recorded for *C. cyanocephala*.

15. **C. longicaulis** Peck, Torr. Bot. Club Bul. **25**: 371. 1898; Sacc. Syll. Fung. **16**: 206. 1902. Plate 2, fig. 8.

Type: in N. Y. State Mus. Herb.

"Stem slender, solid, sparingly and irregularly branched above, the branches rather long, simple or sparingly branched, the tips blunt, the whole plant dark brown when fresh, externally dark ochraceous when dry, longitudinally and somewhat irregularly

wrinkled; spores ochraceous, ovate or subelliptical, minutely roughened or echinulate, 6-7.5 μ long, 4-5 μ broad.

"Plant 3.7–5 cm. high; stem about 2.5 cm. long, 2.4 mm. thick.

"Moist ground. Alabama. July. Earle.

"A well-marked and peculiar species readily known by its long stem, uniform dark brown color fading externally in the dry plant to ochraceous and by the longitudinally wrinkled stem and branches."

The type specimen is now tawny olive everywhere, flattened, longitudinally wrinkled, and of rather equal diameter in all parts; at least some basidia with 4 sterigmata; spores intensely colored, finely echinulate, with spore body 6–8×4–5 μ. The spores are smaller and with smaller projections than those of the three preceding species.

16. **C. xanthosperma** Peck, N. Y. State Mus. Bul. 94: 21. 1905; Sacc. Syll. Fung. 21: 431. 1912. Plate 3, fig. 15.

Type: in N. Y. State Mus. Herb.

"Stem very short, firm, solid, divided into numerous branches, white, sometimes becoming red where wounded, ultimate branches short, blunt or obtusely dentate at the apex, the axils rounded, the whole plant white, becoming yellowish or cream-colored with age; spores pale yellow, oblong, .0005–.0006 of an inch long, .00016–.0002 broad, slightly and obliquely pointed at one end.

"Woods. Smithtown, Suffolk Co. August.

"It forms tufts about 2 inches high."

Inspection of the base of the fructifications indicates that they probably grew on the ground; the fructifications are now warm buff to cinnamon-buff; basidia with 4 sterigmata; spores in preparation appear colored in contrast with adjacent tissue, even, flexuous, 14×4 μ.

This species seems noteworthy by having a white fructification and colored spores; perhaps the yellowish or cream color assumed with age is due to maturing spores.

17. **C. albida** Peck, N. Y. State Mus. Rept. 41: 79. 1888; Sacc. Syll. Fung. 9: 249. 1891. Plate 3, fig. 16.

Type: in N. Y. State Mus. Herb.

"Plants 2 to 4 in. high, whitish; stem short, thick, generally tapering downwards, divided above into a few short, thick, much-

branched ramuli, ultimate branches densely crowded, terminating in a few short, blunt teeth; flesh firm, dry, whitish, taste tardily acrid, then bitter; spores oblong, pale ochraceous, .0005 to .0006 in. long, .0002 broad.

"Ground in thin woods. Menands. August.

"The species has the structure of *C. botrytis* and *C. flava*, but it is readily distinguished from these by its uniform whitish color, the tips of the branches being concolorous."

The four fructifications of the type are between avellaneous and tawny olive with the tips somewhat resinous colored; fructifications probably contracted greatly in drying for they are now longitudinally rugose and channelled; spores slightly colored, even, flexuous, 12–15×4–5 μ.

18. **C. secunda** Berk. & Curtis, Grevillea 2: 7. 1873; Sacc. Syll. Fung. 6: 702. 1888. Plate 1, fig. 4.

Type: in Curtis Herb. and in Kew Herb. probably.

"Caudice crassiusculo cito diviso; ramis curvatis secundis; apicibus apiculatis. No. 534. Car. Sup. No. 991. Santee River.

"Pale yellow; stem moderately thick, soon divided, branches curved, all leaning one way, tips shortly divided, apiculate; spores yellow. *C. spinulosa*, Schwein. Herb."

As shown in the photograph, the stem is very short and soon divided into the branches; the fructification is now everywhere snuff-brown but this may be due in some degree to the specimen having been treated at some time with a fluid, probably for poisoning, which dissolved matter so that the paper on which the specimen is mounted is stained about the fructification; spores ochraceous where occurring as powder in axils of the branches, pale colored under the microscope, barely rough but not showing spines, 10–13×3½–4½ μ.

19. **C. crassipes** Peck, N. Y. State Mus. Bul. 67: 27. 1903; Sacc. Syll. Fung. 17: 195. 1905. Plate 7, fig. 51.

Type: in N. Y. State Mus. Herb.

"Stem thick, firm, solid or sometimes with a cavity at the base, glabrous white or whitish, repeatedly branched above, the branches very numerous, crowded, solid, terminating in obtuse or obtusely dentate tips, whitish or sligthly yellowish; spores oblong, uninucleate, .0006–.0007 of an inch long, .00025–.0003 broad, with an oblique apiculus at the base.

"Plant 3–6 inches high, 2–4 inches broad in the widest part, with the short stem about 1 inch thick. In woods and groves. Sandlake. August.

"The flesh of the stem when cut or broken slowly assumes a smoky brown color."

Fructification now tawny olive; spores pale colored, barely rough under immersion objective, flexuous, 13×4–4½ μ.

The type of *C. crassipes* has a thicker stem than that of *C. secunda* but is very similar in other characters.

20. **C. testaceoflava** var. **testaceoviridis** Atkinson, Ann. Myc. **6**: 58. 1908; Sacc. Syll. Fung. **21**: 427. 1912. Plate 3, fig. 17.

Type: in Cornell Univ. Herb.

"Plants clustered, extreme bases slightly joined; tufts 4–5 cm. high, 3–4 cm. broad; trunks short, 1–2 cm. high, 4–6 mm. stout, above abruptly branched, terminal branches somewhat enlarged and pluridentate; trunks and branches pale drab, tips olive green when fresh; spores oblong, roughened, 10–12×4 μ.–C. U. herb., No. 10593, ground, woods, Blowing Rock, N. C., A. B. Troyer, Aug. 19–Sept. 22, 1901."

The fructification is now everywhere fuscous, and the smaller branches longitudinally rugose; spores slightly colored, rough, 10–12×4–4½ μ.

21. **C. abietina** Persoon in Roemer, Neues Mag. Bot. **1**: 117. 1794; Comment. Clav. 46. 1797; Syn. Fung. 588. 1801; Myc. Eur. **1**: 164. 1822; Fries, Syst. Myc. **1**: 469. 1821; Hym. Eur. 671. 1874; Sacc. Syll. Fung. **6**: 701. 1888; Morgan, Cincinnati Soc. Nat. Hist. Jour. **11**: 89. 1888; Cotton & Wakefield, Brit. Myc. Soc. Trans. **6**: 174. 1919. Plate 5, fig. 28.

Illustrations: Cooke, Handb. **1**: 330. *text f. 88;* Fl. Dan. *pl. 2030, f. 2;* Greville, Crypt. Fl. *pl. 117;* Hard, Mushrooms, *text f. 390;* Patouillard, Tab. Anal. Fung. *f. 566.*

Plants much branched, forming spherical tufts 3–5 cm. high, tough, deep dull ochraceous in color, becoming greenish when bruised; smell strong, taste bitter; stem short, thick, whitish, downy, with a slightly rooting base, becoming greenish; branches slender, 1–2 mm. thick, erect, repeatedly forked, cylindrical or compressed, longitudinally wrinkled when dry, apices pointed or bifid, axils acute; basidia with 4 sterigmata; spores deep ochraceous in the mass, copious, finely rough, pip-shaped, 7–10×3–5 μ (average 7–8×3–5 μ).

On the ground in coniferous woods.

The above is based on the description by Cotton and Wakefield, who add further: "Distinguished from all other British species by turning green when bruised." In working with American gatherings the bitter taste of European specimens should be kept in mind and noted if detected; the spores are glued together in small masses in the specimens from Germany in the exsiccati cited below, and the trunk is short and soon branched in these specimens and in the European illustrations of the species. *C. abietina* has been reported from Ohio by Morgan and by Hard.

Specimens examined:

Exsiccati: Klotzsch, Fungi Germ., 43; Lindhart, Fungi Hung., 51; Rabenhorst, Herb. Myc., 314; de Thümen, Myc. Univ., 410.

22. **C. flavula** Atkinson, Ann. Myc. **6**: 56. 1908; Sacc. Syll. Fung. **21**: 428. 1912. Plate 4, fig. 20.

Type: in Cornell Univ. Herb.

"Plants buff yellow arising from a tough and thick subiculum which produces many stems which branch many times dichotomously, are flexuous and end in minute, pointed tips. The whole plant is tough. Spores pale yellow, oblong, smooth or some very slightly roughened, 9–12×3–3,5 μ.—C. U. herb., No. 14113, on leaves (pine and oak) Fall Creek bank below Chemical building, C. U. Campus, Ithaca, N. Y., C. Thom., Oct. 22, 1902."

The fructifications are soft and tender when moistened and of rather dry composition, now everywhere pinkish buff to warm buff; the subiculum upon which the many fructifications stand is a mycelium composed of interwoven hyphae which covers, and whose strands are incorporated in, a mass of pine needles; spores slightly colored, minutely rough, about 10×4 μ.

This species is noteworthy by the grouping of the fructifications on a subiculum, dichotomous branching of the slender fructifications, buff color, and rough spores.

23. **C. leucotephra** Berk. & Curtis, Grevillea **2**: 7. 1873; Sacc. Syll. Fung. **6**: 712. 1888. Plate 4, fig. 21.

Type: in Curtis Herb. and probably in Kew Herb.

"Caudice communi crassiusculo, ramis strictis apicibus furcatis acutis brunneis basi albo-tomentosis. No. 6362. Car. Amongst fallen leaves.

"About 2 inches high, with the thickish common base; branches straight, forked and apiculate at the tips, tomentose below."

The type specimen in Curtis herbarium is now fragmentary, consisting of the main trunk and bases of branches and fragments of some branches, with all parts colored clove-brown; dried trunk strongly longitudinally furrowed, now showing none of the tomentose covering at the base; spores colored, minutely rough, 9–10×3½–4½ μ. Sections mounted on the sheet with the type show the hymenial surface free from hairs, cystidia, etc. The fluid used in poisoning the specimen has dissolved a pigment from the fructification and stained the herbarium sheet dark brown in the vicinity of the specimen. The type specimen was collected at Hillsborough, North Carolina.

The main stem is suggestive of the stem of *C. spiculospora* and *C. grandis* but these species have the spores more intensely colored, strongly echinulate, and larger.

24. **C. flavobrunnescens** Atkinson, Ann. Myc. 7: 367. 1909; Sacc. Syll. Fung. 21: 427. 1912. Plate 4, fig. 22.

Type: in Cornell Univ. Herb.

"Plants very much branched, 5–7 cm. high, 4–6 cm. broad. Trunk short or entirely absent. In latter case branches arising from extreme base. Trunk when present, 0,5–1 cm. in diameter. Primary branches stout, 4–8 mm. in diameter. Branches repeatedly dichotomous. Axils usually rounded or arcuate. Branches sometimes anastomosing, more or less flexuous. Tips minutely dentate. Color uniform yellow except extreme base which is white. Plants very brittle, bruises turn brown and become water soaked. Spores yellow, subelliptical, pale yellow under microscope, minutely roughened 7–9×3 μ.—C. U. herb., No. 22639, ground, woods, Battle's Park, Chapel Hill, N. C."

The original specimen has become in the herbarium tawny olive, more or less discolored olive-brown, now odorless, not noteworthy by anastomosis of the branches, tips of branches notably dentate; spores are an ochraceous powder in some places on surface of fructification, colored under the microscope, minutely rough, 7–9×3½–4 μ.

C. flavobrunnescens and *C. leucotephra* were both described from collections made in North Carolina; the original specimens agree in color, spore characters, and characters of the stems.

Perhaps *C. flavobrunnescens* may be a synonym of *C. leucotephra.*

25. **C. stricta** Persoon, Usteri Ann. Bot. **15**: 33. 1795; Comment. Clav. 45. *pl. 4. f. 1.* 1797; Syn. Fung. 588. 1801; Myc. Eur. 1: 163. 1822; Fries, Syst. Myc. 1: 468. 1821; Hym. Eur. 673. 1874; Berkeley, Outl. Brit. Fung. 281. *pl. 18. f. 5.* 1860; Sacc. Syll. Fung. **6**: 705. 1888; Peck, N. Y. State Mus. Rept. **22**: 87. 1869; Morgan, Cincinnati Soc. Nat. Hist. Jour. **11**: 89. 1888; Cotton & Wakefield, Brit. Myc. Soc. Trans. **6**: 174. 1919. Plate 4, fig. 23.

C. stricta var. *fumida* Peck, N. Y. State Mus. Rept. **41**: 86. 1888. Plate 5, fig. 29.

Illustrations: Persoon, *loc. cit.;* Berkeley, *loc. cit.*

Fructifications branched, 3–5 cm. high, gregarious, tough, ochraceous, tinged with vinous (or pale pinky buff), apices pale yellow; smell strong, spicy, taste bitter; stem distinct, thick, short, tough, with root-like strands of white mycelium at base; branching irregularly dichotomous, axils acute; branches slender, cylindric or sometimes compressed, erect, attenuated, the apices somewhat pointed, solid, slightly incurved; basidia 4-spored; spores ochraceous in the mass, almost hyaline by transmitted light, pip-shaped, almost even, 7–10×3–5 μ.

On rotten wood—sometimes, at least, of frondose species. Maine to Idaho. September and October. Probably common and widely distributed.

This species is distinguished by its occurrence on rotten wood, white, cord-like mycelium, and bitter taste.

C. stricta var. *fumida* Peck, *loc. cit.,* was described as follows: "The whole plant is of a dingy, smoky-brownish hue. Otherwise as in the typical form. Catskill mountains. September. In the fresh state the specimens appear very unlike the ordinary form, but in the dried state they are scarcely to be distinguished."

Fig. 29 is from a photograph of the type of var. *fumida;* this fructification is now clay color for the region of the smaller branches, a little darker towards the base; spores colored, slightly rough, 8×4 μ. There seems little reason for not merging this proposed variety with the species.

26. **C. acris** Peck, N. Y. State Mus. Rept. **54**: 155. *pl. H. f. 37–39.* 1901; Sacc. Syll. Fung. **21**: 426. 1912. Plate 5, fig. 30.

Type: in N. Y. State Mus. Herb., and part of type collection in Burt Herb.

"Stem short, branching from near the base, the branches repeatedly and subpalmately branched, sometimes compressed, tough, solid, reddish incarnate, whitish within, tips acute, whitish or concolorous, the axils often rounded; taste acrid; mycelium white; spores broadly elliptic, pale ochraceous, .00024–.0003 of an inch long, .00016–.0002 broad.

"Much decayed wood of coniferous trees. Floodwood. August. It forms tufts 1.5–3 inches high and nearly as broad."

When fresh the fructifications were between capucine-orange and cinnamon buff and slowly acrid to the taste, they have become pinkish buff in the herbarium and lost the acridity; spores slightly colored under the microscope, minutely rough, 6–7× 4–4½ μ.

C. acris differs from *C. stricta* by the acrid taste and slightly smaller spores.

27. **C. tsugina** Peck, N. Y. State Mus. Bul. **67**: 27. 1903; Sacc. Syll. Fung. **17**: 196. 1905. Plate 5, fig. 31.

Type: authentic specimen collected at Piseco, Adirondack Mountains—probably the type—in N. Y. State Mus. Herb.

"Stem very short, glabrous, branching from the base, solid, the branches few or many, suberect, sometimes crowded, flexible, rather tough, solid, terminating in acute tips; young plants and growing tips creamy yellow, older parts and mature plants vinaceous cinnamon or reddish brown; spores ochraceous, elliptic, .0003 of an inch long, .00016 broad.

"Plants 1–3 inches high, nearly as broad in the widest part. Prostrate, decaying trunks of hemlock, *Tsuga canadensis*. Adirondack mountains. July and August. Closely allied to *C. abietina*, from which it differs in its naked stem, in having no bitter flavor and in wounds not assuming a green color."

The hymenial portions are now cinnamon-brown and portions of the trunk and axils cream-buff; spores slightly colored, minutely rough, 8–9×3–4 μ. Peck did not record absence of acridity for this species, but, unless not at all acrid, the species seems not distinguishable from *C. acris*.

28. **C. cervicornis** A. L. Smith, Linn. Soc. Bot. Jour. **35**: 10. 1901; Sacc. Syll. Fung. **17**: 194. 1905.

Type: probably in Herb. of Brit. Mus.

"Lignicola, 8 cm. alta, basi simplici, subtereti, 2 cm. alta; ramis subdichotomis, supra dumosis, compressis, siccitate sulcatis; planta tota carnea, dein cinnamomea, velutino-pruinosa; sporis ellipticis, echinulatis, flavido-brunneis, 6 μ×8 μ.

"Growing in clumps on rotten wood, Prince Rupert's [Dominica, W. I.], March 1894. No. 917.

"Among rotten leaves, St. Aroment, Aug. 1892. No. 419.

"The flattened branches and the brownish echinulate spores seem to indicate *Thelephora* rather than *Clavaria* for this species, but the hymenium covers the whole surface of the plant and necessitates the placing of it in the latter genus."

I have seen no specimen of this species; the colored, echinulate spores seem to show relationship with the *C. cyanocephala* group of species, from all of which this differs in the subglobose spores and occurrence on wood.

29. **C. pinicola** Burt, n. sp. Plate 5, fig. 32.

Type: in Mo. Bot. Gard. Herb.

Fructifications rarely solitary, usually in clusters of 2–6 from a common white mycelium, slender, of rather uniform diameter throughout, sometimes simple but usually once to thrice dichotomously forked, the branches cylindric, spreading, drying everywhere buffy brown, the apices acute; spores slightly colored under the microscope, even, 7½–9×4½–5 μ.

Fructifications 1–3 cm. long, trunk and main branches 1/3–3/4 mm. in diameter.

On bark of log of *Pinus contorta*. Priest River, Idaho. Oct. 10, 1920. *J. R. Weir, 16946*, type (in Mo. Bot. Gard. Herb., 57689).

C. pinicola is very distinct from any other American species; it is related in aspect to *C. delicata* Fr., represented in Curtis Herbarium by an authentic specimen from Fries, which has hyaline spores 5–6×2½ μ. *C. delicata* is more fully described as No. 106 of the exotic species. *C. byssiseda* is of somewhat similar aspect but has hyaline spores 12–16 μ long.

30. **C. brunneola** Berk. & Curtis, Linn. Soc. Bot. Jour. **10**: 338. 1868; Sacc. Syll. Fung. **6**: 711. 1888. Plate 3, fig. 24.

Type: in Curtis Herb. and probably in Kew Herb.—Also distributed in Wright, Fungi Cubenses Wrightiani, 462.

"Helvola; stipite cylindrico tenui parce diviso; ramis 1–2 furcatis, ultimis longis obtusis cylindricis patentibus. [Cuba, C. Wright, 239.]

"On banks. November. About 1 inch high."

The fructifications are now drab, with all parts of rather uniform diameter and cylindric; spores slightly colored under the microscope, even, pointed at apex as well as at base, 13–15×9–10 μ.

C. brunneola is noteworthy by its very large, pointed spores and by the small, few and divaricately branched fructifications. The tissue seemed rather dry and tough when moistened in making a preparation; perhaps this species should be transferred to *Lachnocladium* when characters of the specimens in vegetative condition are better known.

31. C. flaccida Fries, Syst. Myc. **1**: 471. 1821; Hym. Eur. 671. 1874; Icones Hym. **2**: 99. *pl. 199, f. 4.* 1884; Peck, N. Y. State Mus. Rept. **32**: 36. 1879; Cotton & Wakefield, Brit. Myc. Soc. Trans. **6**: 175. 1919. Plate 4, figs. 25, 26.

Illustrations: Fries, *loc. cit.*

Type: authentic specimen from Fries in Curtis Herb.

Fructifications branched, small, 3–4 cm. high, gregarious, rather tough but flaccid, bright ochraceous in color, tips paler, base whitish, does not turn green on bruising; smell and taste slight, pleasant; main stem very short, white, with white floccose mycelium; branches very crowded, repeatedly forked, erect, upper axils rounded, the pointed terminal branches usually curving inwards towards each other, solid; flesh white; basidia with 4 sterigmata; spores not copious, ochraceous, very finely punctate, pip-shaped, 6–8×3–5 μ (average 6–7×3 μ), sometimes with a hyaline basal tip.

Among moss and leaves in coniferous woods.

Cotton and Wakefield add further: "Somewhat resembling *C. abietina,* but the whole fungus is more flaccid and does not turn green when bruised. Stem sometimes up to 1.75 cm. long, at others almost obsolete. Mycelium whitish, creeping over leaves, etc."

The specimen from Fries in Curtis Herb., fig. 26, now between fuscous and mouse-gray, is composed of many closely arranged branches; spores copious, distinctly colored, distinctly rough, 6×3 μ, glued together in small groups to a notable degree in the preparation.

32. C. pusilla Peck, Buffalo Soc. Nat. Sci. Bul. **1**: 62 Jl. 1873; N. Y. State Mus. Rept. **25**: 83. 1873; Sacc. Syll. Fung. **6**: 708. 1888. Plate 4, fig. 27.

Type: in N. Y. State Mus. Herb.

"Stem slender, solid, rather tough, much and irregularly branched; branches unequal, divergent; tips acute.

"Plant scarcely 1′ high, yellowish.

"Ground under spruce and balsam trees. North Elba. September.

"This plant is distinguished from *C. tetragona* by its terete stems and irregular ramification."

The fructification is now drab, with stem somewhat olive-buff; spores colored, minutely rough, 4½–6×2½–3 μ, glued together in small masses.

The photographs show the type of *C. pusilla* closely resembling in aspect the specimen of *C. flaccida* from Fries.

33. C. circinans Peck, N. Y. State Mus. Rept. **39**: 43. *pl. 1. f. 21–22.* 1886; Sacc. Syll. Fung. **6**: 704. 1888.

Plate 5, fig. 33.

Type: in N. Y. State Mus. Herb.

"Stem short, solid, dichotomously or subverticillately branched; branches slightly diverging or nearly parallel, nearly equal in length, the ultimate ones terminating in two or more short acute concolorous ramuli; spores ochraceous.

"Plant 1 to 2 in. high, obconic in outline, flat topped, appearing almost as if truncated, pallid or almost whitish in color, generally growing in imperfect circles or curved lines.

"Under spruce and balsam trees. Adirondack mountains. Aug."

Fructifications are now pinkish buff everywhere—the tint of *Coniophora polyporoidea,*—often rising from a whitish mycelium on the leaf mold and binding the particles of the latter together; basidia with 4 sterigmata; spores colored in the mass, nearly hyaline, minutely rough, flexuous, 7½–9×3–3½ μ.

I have collected this species near Silver Lake, Vermont. It has been distributed from New Hampshire in Reliquiae Farlowianae, No. 335.

34. C. flavuloides Burt, n. sp. Plate 5, fig. 34.

Type: in N. Y. State Mus. Herb. under the name *Clavaria subtilis*.

Fructifications up to 3 cm. high, gregarious, many times dichotomously branched, becoming pinkish buff in the herbarium, the branches very slender, drying compressed, curving together, with rounded axils; white mycelial strands at base of stems permeate the leaf humus and bind it together; spores copious, slightly colored under the microscope, 6×3 μ, slightly rough under an immersion objective.

Type: on coniferous leaf humus. North Elba, New York. Sept. 10, 1910. *C. H. Peck.*

This is *Clavaria subtilis* Pers. as understood by Peck, but *C. subtilis* has white spores according to European authors. *C. gracilis* Pers. is said by Fries to differ from *C. subtilis* in having ochraceous spores, and *C. flavuloides* may prove eventually a synonym of *C. gracilis* but since I can find only a vague description of the latter and no original illustration and no specimens in exsiccati, it seems best to give to the American gathering a distinct name. *C. flavuloides* has the general aspect of *C. flavula* but lacks the subiculum over the ground and has smaller spores.

35. C. fragrantissima Atkinson, Ann. Myc. **6**: 57. 1908; Sacc. Syll. Fung. **21**: 427. 1912. Plate 5, fig. 35.

Type: in Cornell Univ. Herb.

"Plants fragrant, pale ochraceous buff, very much branched dichotomously from a single trunk; tips 2–3, conic. Spores 4–5½ ×2½–3 μ, smooth, granular, only slightly tinged with yellow, subelliptical, pointed at side of one end.—C. U. herb., No. 13743, ground, Cascadilla woods, C. Thom., Sept. 22, 1902; No. 15323, ground under pine trees, Beebe Lake woods, Fall Creek, July 30, 1903, Thom., Ithaca, N. Y."

The fructifications are now cream-buff, not notably dichotomous but rather with a tendency to branch along one side of the fructification; prominent mycelial strands extend from base of the stem into the substratum; spores slightly colored, even as seen with usual 4-mm. objective but minutely rough when viewed in glycerine mount with oil-immersion objective, 4½–6× 2½–3 μ. The fragrant odor of the fresh specimens is no longer perceptible.

36. **C. myceliosa** Peck, Torr. Bot. Club Bul. **31**: 182. 1904; Sacc. Syll. Fung. **17**: 196. 1905. Plate 6, fig. 37.

Type: in N. Y. State Mus. Herb.

"Stem slender, solid, irregularly branched above, tawny, with an abundant mycelium which forms whitish, branching strands among decaying leaves and twigs; branches short, divergent or wide spreading with few branchlets, colored like the stem, the ultimate branchlets mostly acute, whitish; spores subglobose, 4 μ long. Scattered or gregarious, 1–2.5 cm. tall, stems about .5 mm. thick.

"Among fallen leaves and twigs under redwood trees. Mountains near Stanford University, California. December. E. B. Copeland.

"The abundant rhizomorphoid mycelium is a marked feature of this species. The plant is inodorous but has a slight peppery taste. It is allied to our eastern *C. pusilla*, but it is a smaller, more slender plant with the slender stem branched above only, and with the few short branches more widely spreading."

The fructifications are now Saccardo's umber, with conspicuous and numerous, whitish mycelial strands at the base ramifying among the humus of decaying redwood leaves; spores colored, rough, 4–4½×2½–3 μ, glued together in small masses.

This species is noteworthy by its slender form, branching above, prong-like branches, and peppery taste.

37. **C. Kunzei** Fries, Syst. Myc. **1**: 474. 1821; Hym. Eur. 669. 1874; Berkeley, Outl. Brit. Fung. 280. 1860; Peck, N. Y. State Mus. Rept. **24**: 81. 1872; Sacc. Syll. Fung. **6**: 697. 1888; Cotton & Wakefield, Brit. Myc. Soc. Trans. **6**: 177. 1919.
Plate 5, fig. 36.

C. chionea Persoon, Myc. Eur. **1**: 167. 1822.—See Cotton & Wakefield, *loc. cit.*

Illustrations: Quelet, Champ. Jura et Vosges 3:16. *pl. 2. f. 11.*

Fructifications 5–12 cm. high, branched, isolated or gregarious, brittle, ivory to creamy white, base sometimes pink; smell none, taste pleasant; stem usually distinct, 1–2 cm. long, 3–5 mm. thick, but sometimes absent; branching irregularly dichotomous or irregular, loose or rarely compact, the branches erect or spreading, cylindric or slightly compressed, often elongated, 2–5 mm. thick, even, solid, axils lunate, apices blunt or pointed; basidia with 4 sterigmata; spores hyaline, globose, even, 3½–4½ μ in diameter, minutely apiculate.

In long grass in woods and pastures.

Cotton and Wakefield comment further: "This species is very distinct in its beautiful ivory-white color and loosely branched habit. When well grown, it may form tufts 4 to 5 inches high and as much across, but average plants are decidedly smaller. From *C. rugosa* it is distinguished by being branched from the base and by the slender, even (not rugose) branches, and from *C. cristata* by the loose habit, lunate axils, and non-cristate branches. From both it differs in very small spores."

In gatherings in frondose woods among leaves from Vermont, New York, and Michigan, which I have studied, the spores are only about 3 μ in diameter.

38. **C. arborea** Atkinson, Ann. Myc. **6**: 56. 1908; Sacc. Syll. Fung. **21**: 432. 1912. Plate 6, fig. 38.

Type: in Cornell Univ. Herb.

"Plants very much branched dichotomously, curved and sometimes deformed, white to alutaceous, terminal branches rose pink, or yellowish brown probably when old. Basidia 4-spored. Spores obovate, asperulate, white, 3–4×2–3 μ.—C. U. herb., No. 13647, ground, woods north of Varna, N. Y. Whetzel, Aug. 21, 1902."

Fructification now between antique brown and cinnamon-brown, with trunk and main branches pinkish buff; branches not crowded, of rather uniform diameter; spores hyaline, mostly even—only very rarely by prolonged search may one be found obscurely asperulate—subglobose, 4–4½×3½–4 μ.

This seems very near *C. Kunzei.*

39. **C. subcaespitosa** Peck, N. Y. State Mus. Bul. **167**: 39. 1913 Plate 6, fig. 39.

Type: in N. Y. State Mus. Herb.

"Forming dense tufts 7.5–12.5 cm. tall, fragile, white or whitish, the stems united at the base, three to five times dichotomously divided, the terminal branchlets obtuse or subacute, both stems and branches solid, soft, becoming thinner and flattened or angular in drying, flesh white, taste mild; spores broadly ellipsoid or subglobose, 4–5×3–4 μ.

"Ground. Ellis, Mass. September. Mrs. E. B. Blackford and G. E. Morris. Communicated by Miss Ann Hibbard.

"This species may be separated from *Clavaria densa* Pk. by

its greater fragility, whiter color, softer texture and smaller spores. In the dried specimens the stems and branches are much more slender and of a purer white color than in *C. densa.*"

The type specimen is now cream color; spores white in the mass, hyaline under the microscope, minutely rough under a dry objective, minutely spinulose viewed with immersion objective, subglobose, 3½–4½×3–3½ μ. This species may be most surely separated from *C. Kunzei* by the rough spores; recent gatherings from the type locality, now in Mo. Bot. Gard. Herb. and Burt Herb., show furthermore that the outer surface of a cluster of the fructifications is composed of more numerous and finer ultimate branchlets than in *C. Kunzei.*

40. C. cristata Holmskiold ex Fries, Syst. Myc. **1**: 473. 1821; Sverig. Atl. Svamp. 53. *pl. 92. f. 1.* 1861; Hym. Eur. 668. 1874; Persoon, Syn. Fung. 591. 1801; Myc. Eur. **1**: 166. 1822; Berkeley, Outl. Brit. Fung. 280. 1860; Sacc. Syll. Fung. **6**: 695. 1888; Morgan, Cincinnati Soc. Nat. Hist. Jour. **11**: 87. 1888; Peck, N. Y. State Mus. Rept. 48: 211. *pl. 39. f. 8–12.* 1896; Cotton & Wakefield, Brit. Myc. Soc. Trans. **6**: 176. 1919. Plate 6, fig. 40.

Ramaria cristata Holmskiold, Fungi Dan. 92. *pl. 23.* 1799.

Illustrations: Holmskiold, Fries, Peck, *loc. cit.;* Persoon, Comment. Clav. *pl. 2. f. 4;* Hard, Mushrooms, *text f. 393.*

Fructifications 3–8 cm. high, gregarious, fragile, pure white, pinkish white or with a tinge of mouse-gray; smell none, taste distinct; flesh white; stem short, slender or stout; branches numerous, irregular, flattened upwards, and divided at the tips into sharp-pointed branchlets, axils rounded; basidia with 2 sterigmata; spores hyaline, even, apiculate, 9–12×6–8 μ (average 9×7, or 7–8 μ).

On ground in woods. Very common.

Cotton and Wakefield add further: "We have retained this species in the sense in which it is usually understood, but not without some misgivings. It is obviously nearly allied to *C. cinerea,* and small crested forms of the latter are difficult to distinguish from certain forms of *C. cristata.* It is noteworthy also that *C. cristata* usually occurs in more shaded spots, and frequently covered with leaves or screened by logs of wood."

41. C. mutans Burt, n. sp. Plate 6, fig. 41.

Type: in N. Y. State Mus. Herb. under the name *C. Krombholzii.*

Fructifications cespitose, 3–4 cm. high, branched 2 or 3 times, white, drying antimony yellow and somewhat longitudinally rugose, the apices usually acute; spores hyaline, even, subglobose, 7×6 μ.

On ground. Delmar, New York. *C. H. Peck,* type.

The above description is made on dried specimens which are what Peck understood as *C. Krombholzii.* The original description of the latter was made by Fries for some figures by Krombholz of what the latter understood as *C. Kunzei* Fr. For the present European opinion of *C. Krombholzii,* see Cotton & Wakefield, *loc. cit.,* p. 198. *C. mutans* is intermediate between *C. rugosa* and *C. cristata,* having coloration and spore characters of *C. rugosa* and some resemblance in aspect to *C. cristata.*

42. C. rugosa Bulliard, Herb. de la France, *pl. 448, f. 2.* 1789; Fries, Syst. Myc. **1**: 473. 1821; Hym. Eur. 669. 1874; Sacc. Syll. Fung. **6**: 696. 1888; Peck, N. Y. State Mus. Rept. **28**: 53. 1879; Morgan, Cincinnati Soc. Nat. Hist. Jour. **11**: 87. 1888; Cotton & Wakefield, Brit. Myc. Soc. Trans. **6**: 185. 1919.

Plate 6, fig. 42.

Illustrations: Bulliard, *loc. cit.;* Cooke, Brit. Ed. Fungi, *pl. 9. f. 32;* Patouillard, Tab. Anal. Fung. *f. 38;* Quelet, Champ. Jura et Vosges 1. *pl. 20. f. 5;* Krombholz, Nat. Abbild. u. Beschr. Schwämme *pl. 54. f. 13–17,* and *pl. 53. f. 14–17* (type of *C. Krombholzii*); other references in Sacc. Syll. Fung. **19**: 328.

Fructifications simple or slightly irregularly branched, solitary or gregarious, 5–10 cm. high, white or pallid, rather tough, thickened upwards, up to 1 cm. thick, longitudinally wrinkled, solid, apex blunt, basidia with 2 sterigmata; spores hyaline, even, subglobose, 9–11×8–9 μ, or 9–10 μ in diameter.

On ground in woods. Common.

Cotton and Wakefield add further: "This species varies in habit from simple to very branched forms, and the surface may be exceedingly rugose to almost smooth. It is generally recognizable, however, by the distinct, irregular, longitudinal wrinkles and the large spores."

American specimens which I have seen are only about half as large as stated above, and they assume in the herbarium an antimony yellow color which is helpful in recognizing at sight dried specimens of unusual forms of this species; the spores are

also a little smaller in the American gatherings than the dimensions given above.

43. C. rufipes Atkinson, Ann. Myc. **6**: 57. 1908; Sacc. Syll. Fung. **21**: 430. 1912. Plate 6, fig. 43.

Type: in Cornell Univ. Herb.

"Plants entirely white, base of stem tinged rufous, about 2 cm. high, branched like *Clavaria muscoides,* tips blunt and slightly enlarged. Basidia 4-spored. Spores oboval, granular then with an oil drop, smooth, 4–6×2,5–3 μ.—C. U. Herb., No. 14037, ground, Six Mile Creek, Ithaca, N. Y. Whetzel, Oct. 10, 1902."

Stem branched at apex into filiform branches which are now resinous (nearly Sayal brown), the stem tapering downward, now paler than the branches; spores hyaline, even, 4–6×3–4 μ.

C. rufipes is sharply distinct from the other white species by its small size, form suggestive of the fresh water hydra, and small spores. *C. exigua,* our other small species, was described as having a white stem and branches somewhat lavender.

44. C. asperula Atkinson, Ann. Myc. **6**: 54. 1908; Sacc. Syll. Fung. **21**: 430. 1912. Plate 6, fig. 44.

Type: in Cornell Univ. Herb.

"Plants branched from the base often forming broad tufts, 1–4 cm. high, tufts 1–4 cm. broad, entirely white, sometimes after drying becoming more or less discolored, brownish etc., axils of branches rounded, branches more or less divergent or arcuate; tips divergent or arcuate, acute; base of trunk often tomentose. Spores minute, oboval, granular or with a small oil drop, asperulate, 3–5×2–4 μ.—Ground, woods, rather common at Ithaca, N. Y. Some of the collections in the C. U. herb. are as follows No. 13550, Beebe Lake woods, Whetzel, Aug. 13, 1902; No. 15216, Buttermilk Gorge, July 15, 1903, Kauffman; No. 13284, Coy Glen, C. O. Smith, Aug. 4, 1902. Ithaca, N. Y."

My notes on *C. asperulans* apply also to this species. In *C. asperula* the fructifications are a little larger and fewer spores are even than in *C. asperulans* but of the same form, dimensions, and rough wall. The gathering of *C. asperulans* is probably a little less mature than those of *C. asperula.*

I have collected this species in Vermont. It has been distributed from New Hampshire in Reliquiae Farlowianae, 305, under the name *Clavaria corniculata.*

45. C. asperulans Atkinson, Ann. Myc. 6: 55. 1908; Sacc. Syll. Fung. 21: 430. 1912. Plate 6, fig. 45.

Type: in Cornell Univ. Herb.

"Plants 1–4 cm. high, entirely white, in drying often stained flesh-colored, with white mycelium over the base and base of primary branches as in *C. muscoides*, smooth above, repeatedly and dichotomously branched, angles arcuate, branches slightly diverging, terminal branchlets short, acute. Spores white, subglobose, with a prominent short stalk where attached to sterigma, minutely and distantly roughened, with an oil drop, 3–4 μ in diameter.—C. U. herb., No. 22131, ground under pines in mixed woods, Six Mile Creek, Ithaca, N. Y. Sept. 25, 1907, Coil & Humphrey."

Now with trunk pinkish buff and the branches slightly darker —about cinnamon buff; the mycelial coat above mentioned is a cortex like that of many species of *Tremellodendron* but the basidia are cylindric and afforded no evidence of longitudinal septation; many spores even, but some minutely and distinctly rough as stated, about 3–3½ μ.

Lachnocladium vestipes,=*Clavaria vestipes* Peck, should be considered in connection with *C. asperula* and *C. asperulans*.

46. C. nodulosperma Atkinson, Ann. Myc. 7: 368. 1908; Sacc. Syll. Fung. 21: 428. 1912. Plate 6, fig. 46.

Type: in Cornell Univ. Herb.

"Plant stalked, very much branched, 3–4 cm. high, branching 2–3 cm. broad. Stems slender about 3mm. in diameter. Primary branching dichotomous or subpalmate. The branches branching in a similar way, more or less flexuous and often slightly flattened. Axils acute or rounded. Plants entirely white, flour white, soft, flexible not brittle. Spores white, angular to tuberculate like the spores of some species of *Inocybe*, 5–7×3–3,5 μ.—C. U. herb., No. 22641, on ground, mixed woods by Fern Walk near Sparrow's Pond, Chapel Hill, N. C., W. C. Coker, Oct. 2, 08."

Fructifications now between cream-buff and pinkish buff; many branches are flattened, but not all, and have curved together in drying; spores hyaline, with nodular surface, 5–6× 3–4 μ.

47. C. pyxidata Persoon, Roemer Neues Mag. Bot. 1: 117. 1794; Comment. Clav. 47. *pl. 1. f. 1.* 1797; Syn. Fung. 589. 1801;

Myc. Eur. **1**: 165. 1822; Fries, Syst. Myc. **1**: 470. 1821; Hym. Eur. 669. 1874; Peck, N. Y. State Mus. Rept. **33**: 22. 1880; Sacc. Syll. Fung. **6**: 698. 1888. Plate 6, fig. 47.

Illustrations: Persoon, *loc. cit.;* Fl. Dan. *pl. 1304, f. 1.*

Fructifications forming tufts up to 3–10 cm. high, pallid, then tan color and somewhat rufescent; trunk slender, glabrous, branched, the branches and branchlets solid, all cup-shaped at the apex and with the little cups radiate-branched at the margin in a proliferous manner, the terminal ones dentate; spores white in the mass, even, 3–3½×2–2½ μ.

On rotten wood. New Hampshire to Missouri. July to October. Rather common on rotten *Salix* near St. Louis.

Although Cotton and Wakefield, *loc, cit.*, p. 198, regard *C. pyxidata* as an indeterminable species, "possibly an abnormal form of *C. stricta,*" nevertheless it is sharply characterized among the European species, the pyxidate cups suggesting those of a lichen (*Cladonia*) as emphasized by Persoon in the original description but not faithfully shown by the artist in Persoon's accompanying illustration. Good European specimens have been distributed in Krieger, Fungi Sax., 1156 and 1156b, with which our American collections agree well. An American gathering from New Hampshire has been distributed in Reliquiae Farlowianae, 309.

48. **C. Petersii** Berk. & Curtis, Ravenel, Fungi Car. **5**: 33. 1860; Grevillea **2**: 7. 1873; Sacc. Syll. Fung. **6**: 716. 1888. Plate 6, fig. 48.

Type: in Ravenel, Fungi Car. **5**: 33.

"E communi basi ramosa; ramis strictis subfastigiatis apice apiculato divisis rufis. No. 4576 bis. Alabama, Peters. On dead wood.

"About 2 inches high, branched from the very base; branches straight, somewhat fastigiate, rufous, tips apiculate."

The fructifications are now pinkish cinnamon, and branches probably hollow, but this is difficult to determine positively from dried pressed specimens. The branches and branchlets are not cup-shaped at the apex. Long, slender, hyaline, conducting organs are present in crushed preparations; spores hyaline, even, flattened on one side, 4×2–2½ μ.

49. **C. coronata** Schweinitz, Am. Phil. Soc. Trans. N. S. **4**: 182. 1832; Sacc. Syll. Fung. **6**: 712. 1888; Morgan, Cincinnati

Soc. Nat. Hist. Jour. 11: 88. *pl. 2. f. 1.* 1888. Plate 7, fig. 49.

Illustrations: Morgan, *loc. cit.*

Type: in Herb. Schweinitz—no duplicate in Curtis Herb.

"In ligno putrido dejecto Bethlehem.

"C. lignatilis, jam e basi divisa, ramosissima; ramis primordialibus divergentibus demum complanatim aut angulatim compressis, apicibus adhuc divergentioribus truncato-obtusis, in ipsa truncatura coronatis processubus minutis circumcirca Cladoniae more. Substantia subtenaci. Ramis omnibus madido statu quasi subdiaphanis et subviscosis, substriatis; exsiccata autem non cornea fit. Mediocri magnitudine. Colore pallido-cervino."

Fructification of medium size, divided immediately from the base and very much branched; the primary branches divergent, then compressed in a plane or angularly; the final branchlets truncate at the apex and there encircled with a crown of minute processes in the manner of a *Cladonia;* all branches somewhat striate, somewhat diaphanous and somewhat viscous when moist but not horn-like when dry; substance somewhat tough. The original specimen is now between light pinkish cinnamon and pinkish cinnamon, somewhat longitudinally wrinkled; the few spores present are hyaline, even, 3–6×2–3 μ, usually 4×2½–3 μ.

Careful examination failed to show cup-shaped apices of the branches, by the absence of which this species is distinguishable from *C. pyxidata.* Morgan reported this species common on rotten wood in Ohio, repeatedly dichotomously or verticillately branched and forming clusters sometimes several inches in height and extent; his figure agrees closely with my photograph of the type and shows the details better.

50. C. pinophila Peck, N. Y. State Mus. Rept. **35**: 136. 1884; Sacc. Syll. Fung. **6**: 699. 1888. Plate 7, fig. 50.

Type: in N. Y. State Mus. Herb.

"Stems short, more or less tufted, much branched; branches crowded, often compressed above and subdigitately divided, pale-ochraceous, ultimate ramuli rather long, subulate, white; spores oblong or sublanceolate, .0004′ - .0005′ long, .00016′ broad.

"Thin woods under pine trees. East Berne. August.

"The tufts are about one inch high. The spores appear white when caught on brown paper."

The fructifications now have the hymenial portion between

avellaneous and drab and the stem paler—somewhat olive-gray; spores hyaline, even, flexuous, 13½–15×3½–4 μ.

51. C. asterella Atkinson, Ann. Myc. **6**: 55. 1908; Sacc. Syll. Fung. **21**: 431. 1912. Plate 7, fig. 52.

Type: in Cornell Univ. Herb.

"Plants ochraceous, 5–7 cm. high. Trunk short, primary branches open, bases divaricate, axils rounded, upper branches fastigiate. Plants soft, flexible. Spores small, white, oboval, inequilateral in side view, with an oil drop, 4–5×2,5–3 μ, with a few scattered short spines.—C. U. herb., No. 11914, on leaf mold, lower slope Mt. Mitchell, Black Mts. Yancey Co., N. C. G. F. Atkinson, Sept. 1901."

Fructification now pinkish buff; spores hyaline, showing a few slender spines under the immersion objective.

52. C. divaricata Peck, N. Y. State Mus. Bul. **2**: 11. 1887; N. Y. State Mus. Rept. **54**: 171. 1901; Sacc. Syll. Fung. **9**: 249. 1891. Plate 7, fig. 53.

Type: in N. Y. State Mus. Herb.

"Stem short, small, whitish, much branched; branches widely spreading, terete, even or slightly longitudinally wrinkled, more or less curved, pale-ochraceous, the ultimate ones tapering outward and terminating in one or more acute points; spores .0004 to .0005 in. long, .0002 to .00025 broad.

"Tufts 2 to 4 in. high, and nearly as broad.

"Woods. Sandlake. August.

"This is a rare species, and is remarkable for and easily distinguished by its divaricate branches which give to the plant a very spreading, straggling aspect."

The fructifications grew on the ground and are now light ochraceous buff in all parts; branches spongy within, somewhat flattened in drying; spores hyaline, distinctly rough, 11–13× 4½ μ. I noted the spores as rugulose when preparation was first made in aqueous mount and studied with dry objective, but upon reexamination of the preparation, now in glycerine mount, the spores appear distinctly rough, not rugulose, under immersion objective.

53. C. lentofragilis Atkinson, Ann. Myc. **6**: 57. 1908; Sacc. Syll. Fung. **21**: 425. 1912. Plate 7, fig. 54.

Type: in Cornell Univ. Herb.

"Plants 15 cm. high, tufts 12 cm. broad; trunks 2–4 cm. long by 2–3 cm. thick, dividing into several short branches which are repeatedly dichotomously branched, axils slightly rounded; tips short, conic. Trunk gray, branches white, tips soft and fragile. Spores white, oboval to subglobose, asperulate, 4–6 μ in diameter. Taste and odor not marked.—C. U. herb., No. 20242, on very rotten wood in sphagnum swamp, Smithton, L. Isl., N. Y."

The branched portion of the fructification is now somewhat warm sepia and the main trunk and main branches are paler, more ochraceous; spores hyaline, minutely aculeate, subglobose, 6×5 μ.

This is a species very distinct from others known to me and distinguished by its occurrence on wood, large size, and hyaline, subglobose, aculeate spores.

54. C. corniculata Schaeffer, Icones Fung. *pl. 173.* 1763; Persoon, Syn. Fung. 589. 1801; Myc. Eur. **1**: 170. 1822; Fries, Syst. Myc. **1**: 471. 1821; Cotton & Wakefield, Brit. Myc. Soc. Trans. **6**: 181. 1919. Plate 7, fig. 55.

C. muscoides Linn. Spec. Plant. 1183. 1753; Fries, Epicr. 571. 1838; Hym. Eur. 667. 1874; Berkeley, Outl. Brit. Fung. 279. 1860; Peck, N. Y. State Mus. Rept. **47**: 151. 1894.

Illustrations: Schaeffer, *loc. cit.;* Holmskiold, Fungi Dan. *pl. 21;* Patouillard, Tab. Anal. Fung. *f. 564;* Fl. Dan. *pl. 775. f. 3.*

Fructification two or three times branched, 2–4 cm. high, apricot-yellow, a little tough, the stem slender; odor and taste not noteworthy; basidia with 4 sterigmata; spores white in spore collection, even, globose, 5–6 μ in diameter.

On ground in woods. August to October. Probably frequent. Known to me from Vermont to Michigan and Missouri.

C. corniculata may be recognized by its slender stem and branches, apricot-yellow color, and white, even, globose spores. In England it is reported as occurring among grass, especially in fields, but I have found it only in moist, mixed woods.

55. C. Peckii Sacc. Syll. Fung. **9**: 249. 1901. Plate 7, fig. 56.

Clavaria similis Peck, N. Y. State Mus. Rept. **43**: 24. 1890, but not of Boud. & Pat. Jour. de Bot. **2**: 341, 446. *pl. 8. f. 1.* 1888.

Type: in N. Y. State Mus. Herb.

"Caespitose, subtenacious, slender, three to four times di-

chotomously branched, pallid, the ultimate ramuli short, obtuse, the axils rounded; spores subglobose, .00025 in. in diameter, mycelium white.

"Plant 1 to 2 in. high. Woods. Plattsburgh. August.

"This scarcely differs from *Clavaria muscoides*, except in its paler color and in the obtuse tips of the ultimate ramuli."

Fructifications now avellaneous; spores copious, hyaline, even, 7–9×6–7 μ, mostly 7×6 μ.

This should be compared with *C. fastigiata* Holmsk., which Cotton and Wakefield regard as a variety of *C. corniculata*.

56. C. muscoides L. var. **obtusa** Peck, N. Y. State Mus. Rept. **47**: 151. 1894. Plate 7, fig. 57.

Type: in N. Y. State Mus. Herb.

"Tips of the ultimate branches obtuse. Otherwise like the type.

"Under cedar trees. Canada. September. Macoun."

Fructification now Sayal-brown; spores hyaline, even, subglobose, 5–6×4½–5 μ.

57. C. fellea Peck, N. Y. State Mus. Rept. **51**: 292. 1898; Sacc. Syll. Fung. **16**: 205. 1902. Plate 7, fig. 58.

Type: in N. Y. State Mus. Herb.

"Clubs about 1 inch high, ochraceous yellow, sparsely and subdichotomously branched; stem terete, solid; branches crowded, nearly parallel, the tips obtuse, concolorous; spores globose, .00024 in. broad; mycelium white.

"Under oak trees. Gansevoort. July. Related to *C. muscoides*. The flavor is bitter and slightly farinaceous."

Fructification now between chamois-color and pinkish buff, the stem paler and with a fibrous surface like blotting paper; basidia with 4 sterigmata; spores hyaline, even, globose, 5–6 μ in diameter.

58. C. Herveyi Peck, N. Y. State Mus. Rept. **45**: 24. 1893. Bot. ed.; Sacc. Syll. Fung. **11**: 135. 1895 Plate 7, fig. 59.

Type: in N. Y. State Mus. Herb.

"Gregarious or subcaespitose, simple or with a few branches, often compressed or irregular, scarcely one inch high, golden-yellow, sometimes brownish at the apex, flesh white, branches when present short, simple or terminating in few or many more or less acute denticles; spores globose, .0003 in. broad, minutely roughened; mycelium white.

"Ground under hemlock trees. Orono, Maine. September. F. L. Hervey.

"Allied to *C. fastigiata* and *C. muscoides* but distinct from both by its more irregular and less branching character and by its larger spores."

The type is now cinnamon-colored, irregular in form, few-branched, compressed, very suggestive of *C. rugosa* in aspect; spores hyaline, even, subglobose, 8–9 μ in diameter.

It is possible that the description was based on specimens of *C. rugosa* unaccompanied by field notes, received in dried condition, and already having the golden color assumed by this species in drying.

59. C. cinerea Bulliard, Herb. de la France, *pl. 354.* 1787; Persoon, Syn. Fung. 586. 1801; Fries, Syst. Myc. 1: 468. 1821; Hym. Eur. 668. 1874; Sacc. Syll. Fung. 6: 695. 1888: Peck, N. Y. State Mus. Rept. 24: 81. 1872; Cotton & Wakefield, Brit. Myc. Soc. Trans. 6: 178. 1919. Plate 8, fig. 60.

Illustrations: Bulliard, *loc. cit.* (unusual form); Dufour, Atlas Champ. *pl. 68. f. 149;* Greville, Scot. Crypt. Fl. *pl. 64;* Patouillard, Tab. Anal. Fung. *f. 154;* Stevenson, Brit. Hym. 2: 290. *text f. 91.*

Fructifications branched, very variable in habit, usually 3–5 cm. in height but sometimes more, solitary or gregarious, grayish or with faint tinge of purple, rather brittle; smell none, taste mild, flesh white; stem more or less distinct, thick, short; branching irregular, repeated, uneven, axils usually acute; branches thick or slender, cylindric or compressed, short, stuffed, erect, wrinkled, apices often toothed; basidia with 2 sterigmata; spores copious, hyaline, even, 7–10×6–8 μ.

On ground in woods. Edible.

C. cinerea has been reported so rarely in the United States that the above description from Cotton and Wakefield—more complete than heretofore available for this species—together with the copy of the original illustration should afford needed aid for critical study of specimens which seem referable here. See also *C. cristata.*

60. C. cinereoides Atkinson, Ann. Myc. 7: 367. 1909; Sacc. Syll. Fung. 21: 431. 1912. Plate 8, fig. 61.

Type: in Cornell Univ. Herb.

"Plants very much branched from base, 7 cm. high, 5–6 cm. broad, trunk absent. Plants uniformly gray when fresh. Base of branches whitish in drying, upper portion of plant becoming pale ochre or buff. Branches dichotomous, slightly clavate, numerous. Axils acute or rounded. Tips usually bidentate, teeth rounded. Plant somewhat tough. Basidia slender, 4-spored, 40–45×7 μ. Spores globose, smooth, white, pedicellate, with large oil drop, 4–6 μ. The plant resembles *Clavaria cinerea* in color when fresh but the spores are much smaller, the branches more slender. In size and shape the spores resemble those of *Clavaria fusiformis* but the plant is very different from that species.—C. U. herb., No. 22640, on ground, among pine needles, mixed woods, hill side by Fern Walk, Chapel Hill, N. C. W. C. Coker."

Stems and branches of nearly uniform diameter, the branches now usually cinnamon-buff, the stems paler and approaching olive-buff and bearing small squamules of matted fibrils; bidentation of tips of branches not prominent; spores hyaline, even, globose, 5–6 μ in diameter.

The dried specimen impressed me as tough rather than fleshy where moistened; if not fleshy when fresh, this species should be transferred to *Lachnocladium*, a transfer favored also by the squamulose stem.

61. C. amethystina (Battara) Bulliard, Herb. de la France, *pl. 496. f. 2.* 1790; Persoon, Comment. Clav. 46. 1797; Fries, Obs. Myc. **2**: 286. 1918 and 1924; Hym. Eur. 667. 1874; Berkeley, Outl. Brit. Fung. 279. *pl. 18. f. 2.* 1860; Sacc. Syll. Fung. **6**: 693. 1888; Cotton & Wakefield, Brit. Myc. Soc. Trans. **6**: 180. 1919. Plate 8, fig. 62.

Coralloides amethystina Battara, Fung. Agr. Arim. 22. *pl. 1. f. C.* 1755—*Ramaria amethystina* Holmskiold, Fungi Dan. 110. *pl. 28.* 1799.

Illustrations: Battarra, *loc. cit.;* Bulliard, *loc. cit.;* Holmskiold, *loc. cit.;* Berkeley, *loc. cit.*

Fructifications branched, 3–4 cm. high, forming small, very compact tufts, lilac or mauve, turning rapidly to yellowish on drying, rather brittle; smell strong, taste tallowy, flesh uniform; stem very short, scarcely distinct; branching irregular, axils not flattened; branches thick, 3–5 mm. in diameter, short, cylindric, not attenuated, erect, smooth, solid, apices blunt; basidia with

2–4 sterigmata; spores hyaline, even, globose, 5–7 μ in diameter.

Among grass in woods and pastures.

Cotton and Wakefield add further: "*C. amethystina* has somewhat the habit of a short thick form of *C. cinerea,* with the deep colored forms of which it has by some authors been confused. When once the true plant has been seen, however, there is no difficulty in distinguishing it by its beautiful violet color (almost as deep as that of *Laccaria laccata* var. *amethystina*), and by its smaller spores."

Peck has collected this species in New York; I have referred a Vermont gathering here.

62. C. amethystinoides Peck, Torr. Bot. Club Bul. **34**: 102. 1907; Sacc. Syll. Fung. **21**: 429. 1912. Plate 8, fig. 63.

Type: in N. Y. State Mus. Herb.

"Clubs 2–4 cm. tall, with few rather short suberect branches, very pale-lilac, becoming drab-gray in drying, the branches often compressed and rugose, more or less pruinose when dry, the tips commonly acute; spores globose, 8 μ in diameter.

"Among sphagnum. Stow, Massachusetts. September. S. Davis.

"This species is evidently related to *C. amethystina* Bull. and *C. Schäfferi* Sacc. From the former it is separated by its different mode of branching and its globose spores; from the latter, to which it seems more closely allied, by its simple, not cespitose mode of growth, by the acute or mucronate tips of the branches, and by the pruinose character of the branches, which also are often rugose and irregular."

Fructifications now with trunk and main branches tawny olive and the terminal branches discolored somewhat olive-brown and pruinose; main stem somewhat compressed and twisted in drying, the terminal branches more cylindric, rather stout, irregular, usually obtuse; spores hyaline, even, subglobose, 6–7×5–6 μ, copious.

63. C. exigua Peck, N. Y. State Mus. Rept. **54**: 155. 1901. Plate 8, fig. 64.

Type: in N. Y. State Mus. Herb.

"Very small; stem slender, dichotomously or somewhat irregularly branching, white, branches delicate lavender color or the lower white toward the base, tips subacute, axils rounded; spores minute, globose, .00008–.0001 of an inch broad.

"Among fallen leaves in woods. Floodwood. September. The whole plant is scarcely more than six lines high. The coloring of the upper part is very delicate and beautiful."

Fructifications now with all parts pinkish buff; spores hyaline, even, 3×2 μ.

64. C. aurantio-cinnabarina Schweinitz, Am. Phil. Soc. Trans. N. S. 4: 183. 1832; Sacc. Syll. Fung. 6: 718. 1888.

Plate 8, fig. 65.

Type: authentic specimen from Herb. Schw. in Curtis Herb., no specimen now in Herb. Schw.

"Locis terrae nudae ad ripas Lehigh in Rhododendretis.

"C. terrestris ad radices tamen arborum, simplex, carnosa, subtenax, fasciculatim proveniens, seriebus saepe elongatis, multiformis, varians a junioribus 3 linearibus ad triunciales adultas altitudine. Deorsum attenuata, medio incrassata, apicem versus iterum attenuata. Clavulis aetate compressis, flexuosis, juventute teretibus. Basi albo-pulverulenta aut pruinata et subbyssacea. Ceterum gaudet colore ex aurantio in cinnabarinum vergenti. Majoribus clavulis interdum ¼ uncialibus crassitie; apice semper obtusiusculo."

Fructifications simple, cespitose, fleshy, somewhat tough, 6 mm. when young to 7 cm. high when full grown, 6 mm. thick, thickened in the middle, attenuated towards both base and apex, cylindric when young, becoming compressed and flexuous, from golden yellow verging into cinnabar; the base white-pulverulent or pruinose and somewhat byssoid; apices always obtuse.

The original specimen is now between cinnamon-drab and Rood's brown, with clubs hollow where shown broken across, somewhat compressed; basidia with 4 stout sterigmata, each 9–13 μ long; spores even, globose, 5–6 μ in diameter, hyaline.

I have gatherings from Vermont and New York which seem referable to this species but usually lack notes as to whether bitter or not, for I was not aware until the appearance of Cotton and Wakefield's recent work that the closely related *C. fusiformis* has a bitter taste; however, in one Vermont collection I did note the taste as pleasant, and in another as with the fragrant odor of *Cantharellus cibarius*. What Hard[1] illustrates and discusses as *C. fusiformis* may have been *C. aurantio-cinnabarina*, for he states that the specimens have an excellent flavor.

[1]Hard, Mushrooms, 472, *text f. 397.* 1908.

65. C. fusiformis Sowerby, British Fungi, *pl. 234, 235.* 1797; Fries, Syst. Myc. 1: 480. 1821; Hym. Eur. 674. 1874; Persoon, Syn. Fung. 601. 1801; Myc. Eur. 1: 178. 1822; Sacc. Syll. Fung. 6: 718. 1888; Peck, N. Y. State Mus. Rept. 23: 53. 1872; Morgan, Cincinnati Soc. Nat. Hist. Jour. 11: 89. 1888; Cotton & Wakefield, Brit. Myc. Soc. Trans. 6: 184. 1919. Plate 8, fig. 66.

Illustrations: Sowerby, *loc. cit.;* Bolton, Hist. Fung. *pl. 110;* Hussey, Ill. Brit. Myc. 1. *pl. 18;* Patouillard, Tab. Anal. Fung. *f. 565;* Cotton, Brit. Myc. Soc. Trans. 3. *pl. 11. f. A.*

Fructifications simple or very rarely branched, densely tufted, connate at the base, 5–8 cm. high, clear canary-yellow; smell none when fresh, taste bitter; flesh whitish; clubs elongated, spindle-shaped, tips acute, often becoming hollow and compressed; internal structure of fine filaments 4–6 μ thick, more or less interwoven, walls sometimes rough; occasional hyphae with dark yellow contents; basidia with 4 sterigmata which are slightly curved; spores globose, even, minutely apiculate, 5–7 (–8) μ in diameter, at first yellow, then colorless.

On ground in woods. August.

Cotton and Wakefield add further: "Known amongst the simple yellow species by the densely tufted habit, the canary-yellow color and the bitter taste."

C. fusiformis has been regarded as common in all parts of the United States but it seems probable that with the heretofore incomplete knowledge of the species, gatherings more properly referable to *C. aurantio-cinnabarina, C. compressa,* and *C. platyclada* have been lumped together here.

66. C. compressa Schweinitz, Am. Phil. Soc. Trans. N. S. 4: 182. 1832; Sacc. Syll. Fung. 6: 709. 1888. Plate 8, fig. 67.

Type: in Herb. Schweinitz, a fragment in Curtis Herb.

"Distinctissima species, Dr. Kampman ex New Jersey communicavit.

"C. majuscula, 2–3 uncias longa, ex ipsa basi crassiuscula vage ramosa, ramis crassis non valde divisis, complanato compressis, quasi canaliculatis, apice obtusatis, deorsum attenuatis. Flavo-alutacea."

Clubs simple, densely tufted, more or less grown together at the middle where in contact, hardly branched, 5–8 cm. high, compressed in a common plane, yellow alutaceous, attenuated below, apices obtuse; smell, taste, and the color of flesh not re-

corded; spores hyaline, even, globose, apiculate, 5–6 μ in diameter, copious.

The specimen in Herb. Schweinitz is now honey-yellow, with 2 or 3 clubs discolored Isabella-color; examination and manipulation when moistened of two clubs at place of fracture where the ends are gone, shows no tendency to become cylindric and favors the view that the inner surfaces of contact of the wall were grown together when fresh by a medullary portion and were not hollow. This species may prove separable from *C. fusiformis* by absence of hollow clubs and bitter taste.

67. C. platyclada Peck, Torr. Bot. Club Bul. **23**: 419. 1896; N. Y. State Mus. Rept. **50**: 114. 1897; Sacc. Syll. Fung. **14**: 237. 1899. Plate 8, fig. 68.

Type: in N. Y. State Mus. Herb.

"Clubs caespitose, more or less connate at the base, simple or forked, rarely with one or two irregular branches, solid, compressed, tapering below into a whitish base, canary yellow, white within, the tips flattened, obtuse, becoming brownish with age; spores globose, .0002 to .00024 in. broad. Tufts 3 to 4 in. high; clubs 2 to 4 lines wide, scarcely more than 1 line thick.

"Woods. Maine. September. Harriet C. Davis.

"The species is closely allied to *Clavaria fusiformis*, from which it is separated by its solid, obtuse, compressed and often forked or branched clubs tapering below into a whitish base."

Clubs now yellow ocher, compressed, solid; spores hyaline, even, globose, 5–6 μ in diameter, minutely apiculate. Since the odor and taste of the clubs when fresh were not recorded, notes on these points should be made for New England collections which seem referable here. *C. platyclada* does not seem distinct from *C. compressa*.

68. C. Macouni Peck, N. Y. State Mus. Rept. 47: 150. 1894; Sacc. Syll. Fung. **11**: 137. 1895. Plate 8, fig. 69.

Type: in N. Y. State Mus. Herb.

"Clubs single or clustered, 6 to 10 lines high, obtuse or subacute, dingy greenish-yellow or pale cinereous; spores minute, elliptical, .0002 in. long, .00012 broad.

"Among mosses under cedar trees. Canada. September. Macoun.

"The species belongs to the section Syncoryne."

The single club preserved as the type is now avellaneous; basidia simple, with 4 sterigmata; spores hyaline, rough, thin-walled, flattened on one side, 4½×3 μ.

69. C. pilosa Burt, n. sp. Plate 8, fig. 70.

Type: in Mo. Bot. Gard. Herb.

Fructifications simple, growing singly or 2–3 in a cluster, when dry 1–2 cm. long, 2 mm. thick, buffy brown to drab, compressed, thickened in the middle, apices obtuse; cylindric, hair-like, hyaline cystidia not incrusted, 6 μ in diameter, protrude in the hymenium up to 30 μ beyond the basidia; spores hyaline under the microscope, even, subglobose, 6–8×6–7 μ.

On humus. Martin Pino, Porto Rico. Feb. 22, 1914. Colls., *J. R. Johnston & J. A. Stevenson, 1453,* type (in Mo. Bot. Gard. Herb., 14540).

The specimen was not accompanied by notes of the characters when fresh. When moistened it seems to me too fleshy for the genus *Lachnocladium.* The species is noteworthy by the presence of hair-like cystidia in the hymenium.

70. C. pallescens Peck, N. Y. State Mus. Bul. **131**: 34. 1909; **139**: 47. 1910; Sacc. Syll. Fung. **21**: 434. 1912.

Plate 8, fig. 71.

Type: in N. Y. State Mus. Herb.

"Clubs simple, loosely cespitose or gregarious, 2.5–4 cm. tall, clavate, soft, fragile, obtuse, pale buff fading to whitish, sometimes minutely rugulose, stuffed or hollow, pale yellow within; stem short, glabrous, 2–4 mm. long, pale yellow; spores oblong or elliptic, white, 9–12×6–8 μ.

"Dry gravelly soil near *Kalmia angustifolia* L. South Acton, Mass. October. S. Davis and G. E. Morris.

"This species is allied to *Clavaria ligula* Fr. from which it differs in its smaller size, in its color becoming whitish or paler with age or in drying, but being lemon-yellow and more persistent within, in its glabrous lemon-yellow stem and in its broader spores. It is apparently a rare but very distinct species."

Fructifications are now chamois-colored, flattened, rugose, stuffed or hollow, and consist of a tuft of 14 clubs arising from a whitish mycelium on the ground; spores hyaline, even, 10–10½ ×4½ μ, copious—none more than 4½ μ thick.

I found several tufts of this species growing among

Polytrichum moss on a dry knoll at Middlebury, Vt.; these clubs were avellaneous when fresh. *C. pallescens* is closely related to *C. fumosa* but its clubs are as closely crowded together at the base as are those of *C. fusiformis* and do not become gray in color. The illustration by Krombholz of *C. fumosa* shows the clubs merely near together at the base but not actually touching one another there, whereas Cotton and Wakefield state that the species has the dense tufted habit of *C. vermicularis*.

71. C. nebulosa Peck, Torr. Bot. Club Bul. **25**: 326. 1898; Sacc. Syll. Fung. **16**: 207. 1902. Plate 8, fig. 72.

Type: in N. Y. State Mus. Herb.; specimen from type collection, *Waghorne, 227*, is in Mo. Bot. Gard. Herb. and has been compared with type.

"Clubs simple, closely gregarious, 2.5–12 cm. high, fragile, hollow, narrowed toward each end, isabelline or clay color, sometimes clouded with darker hues, apt to become blackish in drying; spores oblong or narrowly elliptical, 6–7.5 μ long, 3.5–4 μ broad.

"Sandy soil, Sandy Point, Newfoundland. September. Waghorne."

Has the aspect of a diminutive *C. fistulosa* but with the clubs densely tufted; spores hyaline, even, 6–7×3–3½ μ. Should be compared with *C. fumosa*.

72. C. lavendula Peck, N. Y. State Mus. Bul. **139**: 47. 1910; Sacc. Syll. Fung. **21**: 431. 1912. Plate 9, fig. 73.

Type: in N. Y. State Mus. Herb.

"Tufts 2.5–4 cm. high, densely and subdichotomously branched, the branches compressed, thin, lilac pink when moist, pruinose when dry, the ultimate ones often bidentate, axils rounded; spores minute, 6–8×3–4 μ.

"Chestnut grove. Stow, Mass. July. S. Davis.

"This species is related to *Clavaria amethystina* Bull., but it differs in its flattened branches and smaller spores."

The color of the type has faded to between pinkish buff and light buff; spores hyaline, even, 6×3 μ.

A fine collection of this species from the type locality, communicated by Miss Ann Hibbard and accompanied by water color drawing, notes, and spore collection, shows the spores white in the mass; the clubs are densely tufted, attenuated

downward, sometimes simple clubs with apex obtuse, sometimes with tips bidentate or bilobed, and sometimes divided above into short, obtuse branchlets. Since the fructifications lack a common trunk and are tufted I have located this species in the *Syncoryne*. The specimens bear some resemblance to the original figure of *C. amethystina, pl. 7, fig. 62,* but a closer resemblance in aspect to *C. Schaefferi* Sacc., as given in Schaeffer, Icones Fung., *pl. 172,* and should be compared with European specimens of this species, as suggested by Miss Hibbard.

73. C. vermicularis (Scop.) Fries, Syst. Myc. 1: 484. 1821; Hym. Eur. 675. 1874; Stevenson, Brit. Hym. 2: 298. *text f. 92.* 1886; Sacc. Syll. Fung. 6: 720. 1888; Morgan, Cincinnati Soc. Nat. Hist. Jour. 11: 89. 1888; Cotton & Wakefield, Brit. Myc. Soc. Trans. 6: 183. 1919. Plate 9, fig. 74.

Clavaria vermiculata Scopoli, Fungi Carn. 2: 483. 1772; Berkeley, Brit. Fung. 282. 1860.— *C. fragilis* Holmskiold, p. p., Fungi Dan. 1: 7. *pl. 2.* 1799; Fries, Syst. Myc. 1: 484. 1821; Hym. Eur. 675. 1860; Peck, N. Y. State Mus. Rept. 24: 82. 1872; Sacc. Syll. Fung. 6: 721. 1888; Morgan, Cincinnati Soc. Nat. Hist. Jour. 11: 89. 1888.

Illustrations: Holmskiold, *loc. cit.;* Cooke, Brit. Ed. Fungi, *pl. 4. f. 15;* Stevenson, *loc. cit.;* Hard, Mushrooms, *text f. 395;* Patouillard, Tab. Anal. Fung. *f. 468.*

Fructifications unbranched, densely tufted, somewhat flexuous, brittle, white, about 4–6 cm. high, with the clubs cylindric, sometimes twisted and compressed, even, fragile, becoming hollow, the apex acute; stem not distinct; basidia 30×6–7 μ, with 4 sterigmata; spores white in the mass, even, subglobose, 3–5× 3–4 μ.

On ground. On moist wooded hillsides, grassy borders of woods and in meadows. June to October. Probably common.

Cotton and Wakefield add further: "Easily distinguished among the white species by the densely tufted habit, very fragile clubs, and small spores."

I have studied American gatherings from Vermont, Pennsylvania, Ohio, and Missouri which agree well with the above description. These specimens were not yet in the stage with stem hollow. *C. fragilis* which has been reduced to synonymy by Cotton and Wakefield as the final stage of *C. vermicularis* was originally regarded as distinct by the hollow stem.

74. C. tenuis Schweinitz, Am. Phil. Soc. Trans. N. S. 4: 182. 1832; Sacc. Syll. Fung. 6: 730. 1888. Plate 9, fig. 75.

Type: in Herb. Schweinitz—no specimen in Curtis Herb.

"C. sparsim ex ligno proveniens, fere simplex, affinis *C. mucidae*, et tantum rarius apice furcato. Ceterum tenuis, ¼ unciali longitudine, pallida aut alba, gracilis.

"In muscis nobis ex New York missis."

Clubs simple, solitary, only rarely forked at the apex, white or pallid, slender, tenuous, 6 mm. high.

Three clubs are now to be found; these grow directly from the moss—not from wood. One of these clubs has been brought out for the photographic illustration by slipping about the fructification a small square of white paper so as to cover the moss and have the fructification project natural size against the white background. Each fructification in its present dried condition is 2 mm. long and pale pinkish buff; hyphae 3–3½ μ in diameter, even, long-celled, not nodose-septate; spores hyaline, even, subglobose, 3–3½×3 μ, none seen attached to basidia; basidia not made out.

This species is very distinct from the figure of *Typhula muscicola* in Persoon, Obs. Myc. 2. *pl. 3. f. 2,* a species much larger and often with a tubercule at the base. *Eocronartium,* parasitic on mosses about Ithaca, New York, should be kept in mind in connection with *C. tenuis*. *Eocronartium* has transversely septate basidia.

75. C. misella Berk. & Curtis, Linn. Soc. Bot. Jour. 10: 339. 1868; Sacc. Syll. Fung. 6: 731. 1888. Plate 9, fig. 76.

Type: in Curtis Herb. and probably in Kew Herb.

"Alba, simplex, clavata, obtusa; stipite tenui, basi spongiosa dilatata.

"Attached to Mosses. Not exceeding ½ inch in length; opake when dry. Nearly allied to *C. paupercula,* B. & C., a species from Venezuela, which also grows on moss, but is pellucid and rugose when dry." [Cuba. C. Wright, 222].

Of the several fructifications on the moss plant two were made more conspicuous for the photograph by slipping over the moss small rectangles of white paper so as to afford a white background for the clubs. The clubs are now between cartridge-buff and pinkish buff, with the stem attached in each case to a cluster of 2 or 3 moss leaves, tapering upward slightly to the hymenial

portion, and with the latter somewhat swollen; hyphae hyaline, even, coarse, 4½ μ in diameter; basidia simple, 4-spored; spores hyaline, even, 5–7×3–3½ μ.

76. C. mucida Persoon, Comment. Clav. 55. *pl. 2. f. 3.* 1797; Syn. Fung. 595. 1801; Fries, Syst. Myc. 1: 476. 1821; Hym. Eur. 679. 1874; Sacc. Syll. Fung. 6: 729; Karsten, Finska Vet. Soc. Bidrag Natur och Folk 48: 379. 1889; Peck, N. Y. State Mus. Rept. 24: 82. 1872; Morgan, Cincinnati Soc. Nat. Hist. Jour. 11: 90. 1889; Atkinson, Mushrooms, 203. *text f. 204.* 1901; Coker, Bot. Gaz. 37: 63. *text f. 16-17.* 1904; Hard, Mushrooms, 473. *text f. 398.* 1908. Plate 9, fig. 77.

Illustrations: Persoon, *loc. cit.;* Fl. Dan. *pl. 1376;* Atkinson, *loc. cit.;* Coker, *loc. cit.;* Hard, *loc. cit.*

Clubs gregarious, 6–8 mm. long, small, simple or sparingly ramose-incised, even, naked, white, the apex somewhat yellowish, glabrous; spores hyaline, even, 5–6×2–3 μ.

On green, algal-coated patches of very rotten wood. October and November. Widely distributed, reported common in some localities.

C. mucida is noteworthy by its association with a green, algal coating on very rotten wood. This association has been noted by all the European authors cited above and also by Peck, Morgan, and Coker. Persoon referred to the coating as a green, powdery crust and represented it so faithfully in his type illustration that it was necessary to eliminate the green by a color filter in order to bring out the clubs in the photographic illustration. Fries called the alga a *Chlorococcus,* Karsten, a *Pleurococcus,* and Peck, a confervoid growth. Coker gives a figure showing hyphae running between algal cells and suggests that *C. mucida* may be a basidiomycetous lichen. A specimen in my herbarium, collected at Ithaca, N. Y., by C. O. Smith, shows well the green coating from which the clubs arise; the spores of this specimen have the dimensions published by Karsten. For the negative of *C. mucida* and for other aid in photography I am indebted to Mr. A. F. Camp.

C. mucida var. **Curtisii** Berkeley, Grevillea 2: 17. 1873. Plate 9, fig. 78.

Type: in Curtis Herb. and probably in Kew Herb.

"Clavata brevis lutea apice fusca; stipite albo, e mycelio

parco albo orbiculari oriundo. No. 974 is one forked and narrow.

"On wet-rotting stumps."

A rectangular piece of white paper was slipped back of three fructifications to render them more visible in the photograph. The clubs are now clavate, orange-cinnamon (resin-colored), 3 mm. long; such spores as were found are hyaline, even, subglobose, 4×3½ μ—so few in number that I am not sure they belong to this fungus.

77. C. biformis Atkinson, Ann. Myc. 6: 56. 1908; Sacc. Syll. Fung. 21: 434. 1912. Plate 9, fig. 79.

Type: in Cornell Univ. Herb.

"Plants dull white to sordid yellow, in age tips usually darker, cylindrical, base only slightly more slender, 1–4 cm. high, 0,5–1,5 mm. stout, usually simple, or one to two times dichotomously branched. Basidia 20–25×4–5 μ, 4-spored. Spores oboval, white, smooth, granular or with an oil drop, 3–4×2,5–3 μ.—C. U. herb., No. 13432, leaf mold on ground, woods, Ithaca, N. Y., Aug. 8, 1902; No. 10699, Blowing Rock, Blue Ridge Mts., N. C. Geo. F. Atkinson, Aug. 19–Sept. 22, 1901."

The clubs are now cinnamon-brown, filiform, with a whitish, mycelioid base; spores hyaline, even, 3–4×2½–3 μ, few found.

78. C. subfalcata Atkinson, Ann. Myc. 6: 58. 1908; Sacc. Syll. Fung. 21: 435. 1912. Plate 9, fig. 80.

Type: in Cornell Univ. Herb., consisting of Nos. 11577, 10689, 13675, and 13613—each marked, "Part of type." Arranged for photograph in order given with No. 11577 at the left.

"Plants small, entirely white when fresh, yellowish when dry, rarely white, very slender, 1–3 cm. high, 1 mm. stout; clavula dull white; stipe distinct and transparent, with white mycelium spreading over substratum. Basidia 4-spored. Spores oval-subelliptical, thin-walled, granular, smooth, 7–10×5–7 μ, in age with a large oil drop. Near *C. affinis* but spores not punctate.—C. U. herb., No. 13299, Beebe Lake woods, C. O. Smith, Aug. 5, 1902; No. 13613, McGowan's woods, Long, Aug. 20, 1902; No. 13675, ground, Six Mile Creek, Whetzel, Aug. 22, 1902; No. 18656, on rotten wood on ground, Enfield George, Oct. 22, 1904, Jackson and Whetzel; No. 14108, Fall Creek behind Chemical building, Thom., Oct. 22, 1902 (all these specimens in vicinity of Ithaca, N. Y.); No. 10689, clay bank, Blowing Rock, Blue Ridge

Mts., N. C., G. F. Atkinson, Aug. 19–Sept. 22, 1901; No. 11577 on sphagnum, Grandfather Mt., N. C., G. F. Atkinson, 1901; No. 14468, on leaf mold, woods, Lake Piseco, Adirondack Mts., N. Y., G. F. Atkinson, Aug. 26–Sept. 2, 1902."

No. 13613 is now russet, with a whitish mycelioid mass on the ground at its base; spores hyaline, even, 7–9×4½–6 μ.

No. 11577, on *Sphagnum*, has aspect, structure, and spores very similar to No. 13613, and is noteworthy by the different substratum on which it grew.

79. C. foetida Atkinson, Ann. Myc. **6**: 56. 1908; Sacc. Syll. Fung. **21**: 435. 1912. Plate 9, fig. 81.

Type: in Cornell Univ. Herb.

"Plants white, yellow when dry, stipe not distinct, gradually tapering below, 4–6 cm. high, 1,5–2 mm. stout. Odor of garlic. Basidia 2-spored. Spores oboval, granular, then with a large oil drop, 6–9×5–7 μ.—C. U. herb., No. 7740. Coy Glen, Ithaca, N. Y., Aug. 13, 1901. A. M. Ferguson."

Clubs growing on the ground, simple, with hymenial portion honey-yellow, the stem somewhat drab, white at base. I could not find in my preparation spores of the form and dimensions originally published; on the contrary, a few spores present are slightly colored, even, 10–13×4½–5 μ, and some other spores are hyaline, even, 6×3 μ—in both cases too few for me to be sure that they are the spores of this species.

80. C. sphaerospora Ellis & Ev. Jour. Myc. 4: 74. 1888; Sacc. Syll. Fung. **9**: 248. 1891. Plate 9, fig. 82.

Type: in N. Y. Bot. Gard. Herb.

"On the ground in a garden, St. Martinsville, La., July, 1888. Langlois, 1435. Slender, 8–10 cm. high, cinereous or pale mouse-color, loosely branched, ultimate divisions subulate. Spores, (white)? globose, 5–7 diam. The whole plant is quite slender, the common stem below being only about 1–2 mm. thick, and the few upright subundulate branches of about the same thickness throughout."

Clubs many, simple, some sparingly branched above, now light drab; spores copious, hyaline, even, globose, 7 μ in diameter.

Perhaps this species should be in the Section *Ramaria* near *C. amethystinoides* of very similar aspect but more branched and perhaps not specifically distinct.

81. C. filipes Berk. & Ravenel, Grevillea 2: 17. 1873; Sacc. Syll. Fung. 6: 726. 1888. Plate 9, fig. 83.

Type: in Kew Herb., no specimen to be found in Curtis Herb.

"Pallide rufa; stipite filiformi distincto fistuloso, clavula longo cylindrica curvata. On the ground. Car. Inf. Rav. No. 1488.

"Springing from a white mycelium; pale rufous; stem about an inch high, slender, club the same length."

Miss Wakefield has very kindly studied the type of *C. filipes* in Kew Herb. and made the following notes and also the tracing of the specimens reproduced in the accompanying illustration.

"Now brown in color and not in very good condition. The club is distinct from the stalk—the latter looks more horny. At the base of the stalk there is a paler (cream to tan-colored) mycelium, which rather suggests that the clubs have been attached to leaves or small twigs. As to the spores, those which I have figured, 9–11×5–7 μ, seem most likely to belong, though I saw none attached and there were various other spores present. The basidia made out have 4 sterigmata and are cylindric, 10–12 μ in diameter."

82. C. spathulata Peck, N. Y. State Mus. Rept. 27: 100. *pl. 2. f. 20–21.* 1875; Sacc. Syll. Fung. 6: 725. 1888. Plate 9, fig. 84.

Type: in N. Y. State Mus. Herb.

"Simple, pale yellow; club compressed, spatulate, tapering into the slender slightly furfuraceous stem.

"Plant scarcely more than two lines high.

"Dead branches of hickory trees, *Carya alba.* Greenbush. Oct.

"The color is like that of *Spathularia flavida.*"

The clubs emerge from crevices in the bark—sometimes 2 or 3 in a cluster—and are now ivory-yellow; tissue softens when moistened and was probably fleshy; basidia simple; spores which probably belong to this species are hyaline, even, 9–10×4–4½ μ—other spores present are hyaline, even, 4×3 μ—neither kind seen attached to basidia.

83. C. argillacea Persoon, Comment. Clav. 74. 1797; Fries, Syst. Myc. 1: 482. 1821; Hym. Eur. 675. 1874; Peck, N. Y. State Mus. Rept. 24: 82. 1872; Sacc. Syll. Fung. 6: 719. 1888; Cotton & Wakefield, Brit. Myc. Soc. Trans. 6: 191. 1919. Plate 9, fig. 85.

C. ericetorum Persoon, Obs. Myc. 2: 60. 1799; Myc. Eur. 1: 180. 1822; Boudier, Icones, *pl. 175.* 1905-10.

Illustrations: Fries, Obs. Myc. 2. *pl. 5. f. 3;* Boudier, *loc. cit.;* Patouillard, Tab. Anal. Fung. *f. 585.*

Clubs simple, gregarious, 2–5 cm. high, pale greenish yellow, fragile, cylindric or flattened, with one or more grooves, surface often minutely channelled, apex blunt; smell none, taste like tallow; stem distinct, yellowish; basidia with 4 sterigmata; spores hyaline, even, 10–11×5–6 μ (or sometimes 10–14×6–7 μ).

In heathy places.

Cotton and Wakefield add further: "This species is a typical plant of heather moors and similar heathy places."

84. C. corynoides Peck, N. Y. State Mus. Rept. **31**: 39. 1879; Sacc. Syll. Fung. **6**: 726. 1888. Plate 9, fig. 86.

Type: in N. Y. State Mus. Herb.

"Small, simple, clavate; club obtuse, yellowish, or cream colored, gradually narrowed below and losing itself in the short white stem.

"Gregarious, about half an inch high.

"Damp ground by roadsides. Adirondack Mountains. Aug."

Clubs now pinkish buff in all parts; spores hyaline, even, curved, 6–7×2½–3 μ, very similar in long tapering base to those of *C. gracillima.*

85. C. gracillima Peck, N. Y. State Mus. Rept. **28**: 53. *pl. 1. f. 9.* 1876; Sacc. Syll. Fung. **6**: 725. 1888. Plate 9, fig. 87.

Type: in N. Y. State Mus. Herb.

"Simple, very slender, smooth, about 1′ high, rather tough; club acute or acuminate, pale yellow, a little thicker than the long slender distinct bright yellow shining stem.

"Among moss in a pasture. Northville. August. (Plate 1, fig. 9.)

"In this species, as in *C. argillacea,* the hymenium is quite distinct from the stem."

Clubs now light ochraceous buff; spores hyaline, even, or perhaps somewhat rugose, 7–8×3½–4½ μ. I noted the spores as rugulose when examining them in aqueous preparation but am not certain about this upon reexamining them later in the glycerine mount.

86. C. vernalis Schweinitz, Naturforsch. Ges. Leipzig Schrift. **1**: 112. 1822. Plate 9, fig. 88.

C. clavata Peck, Buffalo Soc. Nat. Sci. Bul. **1**: 62. 1873; N. Y. State Mus. Rept. **25**: 83. *pl.1. f.9.* 1873; Sacc. Syll. Fung. **6**: 726. 1888.

"C. simplicissima gregaria apice incrassata subrugosa flava, stipite subpellucido.

"Frequens tempore vernali in terra nuda, gregaria sed sparsa nec conferta, silvulas saepe viginti pedes longas efficit iuxta vias in ericetis, unciae quadrantem alta."

C. clavata Peck, *loc. cit.*

"Simple, straight, clavate, obtuse, smooth, not hollow, yellow when fresh, rugose-wrinkled and orange-colored when dry, 4″–6″ high.

"Damp shaded banks by road-sides. Sandlake. June. The surface of the ground where it grows is covered by a green confervoid stratum."

The type fructifications of the above species in both Herb. Schweinitz and N. Y. State Mus. Herb. have been lost, perhaps by the crumbling away of some of the sandy earth by which attached to the mounting sheet. The earthy remains of both specimens show a greenish algal coating and short mosses like that on a collection by Peck from N. Elba, N. Y. and a gathering in quantity at Sharon, Mass., in May, determined by Dr. Farlow as *C. vernalis*. *C. clavata*. As Peck endorsed on his type sheet *C. clavata* as a synonym of *C. vernalis*—an opinion in which I concur—I am so treating this species.

The spores of the N. Elba specimen are hyaline, even, flexuous, 7½–9×2½–3½ μ; those of the Sharon specimen white in the mass, even, 7–7½×2½–3 μ. The clubs of the Sharon specimen were pinkish cinnamon of Ridgway above, paler below, and white at the base when fresh, 10 mm. long, 1¼ mm. in diameter in the broadest part, and have dried orange-cinnamon.

Specimens of *C. vernalis* from New Jersey were distributed by Ellis in his North American Fungi, 613, and from Massachusetts in Reliquiae Farlowianae, 311.

87. C. inaequalis Müller, Fl. Dan. *pl. 836. f. 1.* 1778; Fries, Syst. Myc. **1**: 481. 1821; Hym. Eur. 674. 1874; Peck, N. Y. State Mus. Bul. **22**: 87. 1869; Sacc. Syll. Fung. **6**: 719. 1888; Cotton & Wakefield, Brit. Myc. Soc. Trans. **6**: 189. 1919.
Plate 9, fig. 89.

Clavaria similis Boudier & Patouillard, Jour. de Bot. 2: 446. 1888.

Illustrations: Fl. Dan., *loc. cit.* For list of others under synonyms and illustrations, see Cotton & Wakefield, *loc. cit.*

Fructifications simple, or very rarely with one or two branchlets, 4–7½ cm. high, usually in small groups but occasionally single; clubs cylindric or flattened, even or with one or more furrows, bright yellow to rich orange, apex obtuse or pointed; stem not distinct; flesh whitish, fibrous; basidia with 4 sterigmata; spores hyaline, white or slightly ochraceous in the mass, subglobose, echinulate, 5–6 (–8) μ in diameter.

Among grass in woods, parks, lawns, etc.

Cotton and Wakefield add further: " This is by far the most frequent of the simple, yellow Clavarias, being found in short grass in a variety of situations every season. It may be distinguished at once from all other yellow species by its subglobose, spiny spores."

I have American specimens from Massachusetts and Vermont, but with the spiny spores only about 4–6 μ in diameter.

88. C. citriceps Atkinson, Ann. Myc. **6**: 56. 1908; Sacc. Syll. Fung. **21**: 434 (as *C. citripes*). 1912. Plate 10, fig. 90.

Type: in Cornell Univ. Herb.

"Plants subclavate, 1,5 cm. high, 2–3 mm. stout, citron yellow, white below, deeper yellow when dry. Spores oval, white, smooth, with an oil drop, 4–5×3 μ.—C. U. herb., No. 13461, ground, Beebe Lake woods, Ithaca, N. Y., C. O. Smith, Aug. 11, 1902."

Clubs growing two together in one instance, somewhat irregular, obtuse, drying rugose and russet, with stem somewhat pinkish buff; spores hyaline, even, 4½–5×3 μ.

89. C. clara Berk. & Curtis, Linn. Soc. Bot. Jour. **10**: 338. 1868; Sacc. Syll. Fung. **6**: 726. 1888. Plate 10, fig. 91.

Type: in Curtis Herb. and also in Kew Herb. probably.

"Simplex, deorsum attenuata, pallide aurantiaca, semipellucida, gracilis, cylindrica, subacuta; hymenio cum basi continuo.

"On the ground. About an inch high." [Cuba. C. Wright, 557].

Clubs simple, attenuated below, pale golden yellow, semipellucid, slender, cylindric, somewhat acute, without a distinct stem.

Clubs now resin-colored, i. e., between vinaceous-russet and Prussian red; spores hyaline, even, subglobose, 4–4½×3–3½ μ.

90. C. laeticolor Berk. & Curtis, Linn. Soc. Bot. Jour. **10**: 338. 1868; Sacc. Syll. Fung. **6**: 725. 1888. Plate 10, fig. 92.

Type: in Curtis Herb. and also in Kew Herb. probably.

"Simplex, intense aurantiaca, cylindrica, obtusa, basi pallidior; stipite indistincto.

"On earth in woods. November. Scarcely 1 inch high." [Cuba. C. Wright, 226].

Clubs simple, deep golden yellow, cylindric, obtuse, with the base rather paler; stem not distinct.

Clubs now cinnamon; spores hyaline, even, $4\frac{1}{2}$–6×4–$4\frac{1}{2}$ μ.

The clubs have not dried quite identical with those of *C. flavella,* but when in fresh condition they should be compared with the description of the latter and also with that of *C. pulchra.*

91. C. pulchra Peck, N. Y. State Mus. Rept. 28: 53. *pl. 1. f. 10.* 1876; Sacc. Syll. Fung. **6**: 725. 1888. Plate 10, fig. 93.

Type: in N. Y. State Mus. Herb.

"Simple, small, about 1′ high, club elongate-clavate, obtuse, yellow, sometimes a little darker at the apex, gradually tapering into the whitish or pale yellow stem-like base.

"Ground and decaying wood in damp shaded places. Northville and Chittenango Falls. August. (Plate 1, fig. 10.)

"A pretty species, associated with *C. fusiformis* in both localities, but differing from it in shape and habit."

Clubs now tawny to brick-red, with the stem pinkish buff; basidia simple, with 4 sterigmata; spores hyaline, even, slightly flattened on one side, $6 \times 4\frac{1}{2}$ μ.

The clubs are not as slender as those of *C. laeticolor;* perhaps other differences may be found when the characters of both species in their fresh condition are better known.

92. C. flavella Berk. & Curtis, Linn. Soc. Bot. Jour. **10**: 338. 1868; Sacc. Syll. Fung. **6**: 726. 1888. Plate 10, fig. 94.

Type: in Curtis Herb. and also in Kew Herb. probably.

"Simplex, gracilis, flavida, cylindrica, acuta, hymenio cum basi angustata confluente; sicca opaca, striata.

"On the ground. About an inch high." [Cuba. C. Wright, 561.]

Clubs simple, slender, yellow, cylindric, acute, the hymenium confluent with the base, drying opaque and striate.

Clubs now have the hymenial portion Prussian red (resin-

colored) and the basal portion somewhat fuscous; spores hyaline, very thin-walled, 6–7×4½–5 μ, probably even, but only a few seen and these do not show an outline sharp enough so that I am certain as to whether even.

93. C. pistillaris Linn. Fl. Suec. 456, No. 1266. 1755; Fries, Syst. Myc. 1: 477. 1821; Hym. Eur. 676. 1874; Sacc. Syll. Fung. 6: 722. 1888; Atkinson, Mushrooms, 202. *text f. 203;* Peck, N. Y. State Mus. Bul. 94: 50. *pl. 93. f. 1–4.* 1905; as *C. pistillaris umbonata,* N. Y. State Mus. Mem. 4: 178. *pl. 66. f. 15–17.* 1900; Cotton & Wakefield, Brit. Myc. Soc. Trans. 6: 193. 1919.

Illustrations: Atkinson, *loc. cit.;* Bulliard, Herb. de la France, *pl. 244;* Batsch, Elenchus Fung. *pl. 11. f. 46;* Dufour, Atlas Champ. *pl. 70. f. 156;* Fl. Dan. *pl. 1255;* Hussey, Ill. Brit. Myc. 1: *pl. 62;* Krombholz, Nat. Abbild. u. Beschr. Schwämme, *pl. 54. f. 1–11;* Quelet, Champ. Jura et Vosges 1. *pl. 21, f. 2;* Hard, Mushrooms, 471. *text f. 396;* Peck, *loc. cit.*

Clubs simple, solitary, clavate or obovate, obtuse, 5–15 cm. high, 1–5 cm. thick in the upper part, whitish, then dingy ochraceous, solid, soft within; flesh white, taste mild, edible; basidia with 2–4 sterigmata; spores ochraceous in the mass, almost hyaline under the microscope, even, 12–16×7–8 μ.

On ground in mixed woods. Probably widely distributed in the United States.

C. pistillaris is easily distinguished by its large, clavate clubs, sometimes split at the apex when very large. The spore dimensions given above are after Cotton and Wakefield; the spores are 9–12×(4–)6½ μ in such American specimens as I have seen. *Craterellus pistillaris,* a rarer species with us, is of somewhat similar aspect but has its clubs truncate.

94. C. ligula Schaeffer, Icones Fung. *pl. 171.* 1863; Fries, Syst. Myc. 1: 477. 1821; Hym. Eur. 676. 1874; Peck, N. Y. State Mus. Rept. 24: 82. 1872; Sacc. Syll. Fung. 6: 722. 1888; Kauffman, N. Y. State Mus. Bul. 179: 92. 1915; Cotton & Wakefield, Brit. Myc. Soc. Trans. 6: 193. 1919.

Plate 10, fig. 95.

Illustrations: Schaeffer, *loc. cit.;* Schmidel, Icones Pl. *pl. 5. f. 1;* Fl. Dan. *pl. 837. f. 1;* Dufour, Atlas Champ. *pl. 69. f. 155.*

Clubs simple, gregarious, clavate, 3–7 cm. high, 5–10 mm. in

diameter in the upper part, much narrowed and downy towards the base, solid, pinkish buff when young, finally cinnamon or approaching Rood's brown, apex obtuse; stem not distinct from hymenial part; basidia with 4 sterigmata; spores hyaline, even, 10–14×3–4 μ in European specimens, 7–12×3–4 μ in American specimens.

On ground and fallen leaves in coniferous woods. New Hampshire, Vermont, New York, Pennsylvania, Ontario, Missouri, Colorado and Idaho—probably more widely distributed. August to October. Probably common.

C. ligula differs from *C. pistillaris* in smaller size, paler color, and slenderer spores. It is usually abundant when found. At Middlebury, Vermont, it formed a fairy ring 5 feet in diameter.

95. C. fistulosa Holmskiold, Fungi Dan. **1**: 15. *pl. 6.* 1790; Fries, Syst. Myc. **1**: 479. 1821; Hym. Eur. 677. 1874; Persoon, Syn. Fung. 599. 1801; Myc. Eur. **1**: 177. 1822; Sacc. Syll. Fung. **6**: 723. 1888; Peck, N. Y. State Mus. Rept. **26**: 72. 1874; Harper, Mycologia **10**: 54. *pl. 4. f. A, B.* 1918; Cotton & Wakefield, Brit. Myc. Soc. Trans. **6**: 194. 1919. Plate 10, fig. 96.

C. Ardenia Sowerby, British Fungi, *pl. 215.* 1797.—*C. pilipes* Müller, Fl. Dan. *pl. 1076. f. 1.* 1792.—Other synonyms in Cotton & Wakefield, *loc. cit.*

Illustrations: in addition to those cited above Fl. Dan. *pl. 1256;* Harper, Mycologia **10**: *pl. 3;* Krombholz, Nat. Abbild. u. Beschr. Schwämme, *pl. 5. f. 19.*

Clubs simple, solitary or 2 or 3 near together, erect, tough, slender, 5–20 cm. high, narrowly clavate, often twisted, even, becoming hollow with age, at first yellowish, then date-brown, villose at the base; contains laticiferous, unseptate, hyphae frequently branched, 6 μ in diameter; basidia with 4 sterigmata; spores hyaline, even, 10–17×7–9 μ —12–16×6 μ in American specimens.

On fallen limbs buried in leaves on the ground in mixed woods and in coniferous swamps. New York to Michigan and in Ontario. September to November. Rare.

C. fistulosa may be recognized by its long, slender clubs which become hollow, and by the spores. See Harper, *loc. cit.,* for account of the forms of this species and of the following species of the same group.

96. C. contorta Holmskiold, Fungi Dan. 1: 29. *pl. 12.* 1790; Fries, Syst. Myc. 1: 478. 1821; Hym. Eur. 677. 1874; Sacc. Syll. Fung. 6: 723. 1888; Harper, Mycologia 10: 55. *pl. 4. f. C.* 1918; Cotton & Wakefield, Brit. Myc. Soc. Trans. 6: 194. 1919. Plate 10, fig. 97.

Illustrations: Holmskiold, *loc. cit.;* Harper, *loc. cit.;* Boudier, Soc. Myc. Fr. Bul. 33. *pl. 1. f. 5;* Fl. Dan. *pl. 1852. f. 1.*

Clubs erumpent, simple or irregularly branched, contorted, 2–3 cm high, pale yellowish drab, darker when moist, fairly tough; branches 4–6 mm. thick, short, blunt, wrinkled, not attenuated, at length hollow; stem not distinct; smell and taste none; latex tubes present; basidia with 4 sterigmata; spores hyaline, even, 14–18×6–9 μ —17–23×8–10 μ according to Cotton and Wakefield for British specimens.

On branches of dead alder, etc. New England, South Carolina, and Michigan. Rare.

It has been claimed that *C. contorta* is a contorted form of *C. fistulosa.* Those who believe otherwise assert its distinctive characters are its erumpent, dwarf, fasciculate habit, paler, more grayish color, entirely glabrous club covered everywhere with the hymenium, larger spores, and occurrence on dead branches still remaining on the tree. I have seen no specimen of *C. contorta.*

97. C. juncea Fries, Obs. Myc. 2: 291. 1818 and 1824; Syst. Myc. 1: 479. 1821; Hym. Eur. 677. 1874; Peck, N. Y. State Mus. Rept. 22: 87. 1869; Sacc. Syll. Fung. 6: 724. 1888; Harper, Mycologia 10: 56. *pl. 5.* 1918; Cotton & Wakefield, Brit. Myc. Soc. Trans. 6: 195. 1918. Plate 10, fig. 98.

Illustrations: Boudier, Icones, *pl. 176;* Harper, *loc. cit.*

Clubs simple, in groups of 2 or 3, filiform, weak, 5–8 cm. high, ½–1½ mm. thick, dirty yellow, then tinged rusty or brownish drab, hollow, hairy at the base; smell none, taste acrid; basidia with 4 sterigmata; spores hyaline, even, 8–12×4–5 μ.

On fallen frondose leaves in woods. New England to Michigan. Abundant locally.

C. juncea may be readily recognized by its long filiform clubs of acrid taste, growing on leaves in woods in periods of prolonged wet weather.

98. C. asperulospora Atkinson, Ann. Myc. 6: 55. 1908; Sacc. Syll. Fung. 21: 433. 1912. Plate 10, fig. 99.

Type: in Cornell Univ. Herb.

"Plants clustered, wood brown, 4–7 cm. high, 2–3 mm. stout, cylindrical, blunt, tapering below. Basidia abruptly clavate, 30×10–12 μ, 4-spored. Spores globose, white, echinulate, pedicellate, 6–7 μ. —C. U. herb., No. 13182, Fall Creek woods, Ithaca, N. Y., Whetzel, Aug. 3, 1902."

Clubs growing on the ground, now fuscous-black; spores hyaline, becoming echinulate, 6–7 μ in diameter, copious.

SPECIES IMPERFECTLY KNOWN

C. (Ramaria) **Berkeleyi** Montagne, Syll. Crypt. 180. 1856; Sacc. Syll. Fung. **6**: 715. 1888.

"Fragilis, e pallido lutescens; caule ascendente tenui ramosissimo, ramis teretibus repetito-trichotomis fastigiatis, ramulis seu divisionibus terminalibus capitato-fasciculatis purpureis acutisque. Caespitem efformat compactum.

"Hab. Ad truncos in locis humidis dejectis. Columbus [Ohio]: Sullivant, Icon. n° 51.

"Desc. Caulis in ligno decumbens, tenuis, teres vel compressus, mox adscendens, luteo-pallescens, 6–8 centim. longus, fastigiato-ramosissimus. Rami repetito-subtrichotomi, quandoque subfasciculati, axillis rotundatis, crassitudine pennam corvinam aequantes, sensim ascendendo attenuati. Ramuli ultimi fasciculato-capitati vel digitati, divaricati, apicibus acutis rubris. Sporae . . . . . Exsiccatione tota planta nigrescit."

C. bicolor Rafinesque, Med. Repos. II. **5**: 363. 1808; Desvaux, Jour. de Bot. **1**: 233. 1808.

"Aggrégée, cylindrique, alongée, bleue; sommet obtus, d'une couleur rose.

"En Virginie."

C. citrina Rafinesque, Med. Repos. II. **5**: 362. 1808; Desvaux, Jour. de Bot. **1**: 233. 1808.

"Cylindrique, fistuleuse, aggrégée, jaunâtre; sommet mince, demi-obtus.

"En Pensylvanie."

C. citrino-fusca Rafinesque, Med. Repos. II. 5: 362. 1808; Desvaux, Jour. de Bot. **1**: 233. 1808.

"Demi-aggrégée, subulée, jaune; sommet brun aigu.

"Dans l'état de Pensylvanie."

C. compressa Berkeley, Ann. & Mag. Nat. Hist. **10**: 383. *pl. 12. f. 16.* 1842, nec Schw.; Sacc. Syll. Fung. **6**: 714. 1888.

Plate 10, fig. 100.

"Pallida, mycelio fibrilloso niveo, stipite compresso, furcato; ramis paucissimis tenuibus cylindricis; apicibus acutis.

"Jamaica. Herb. Mus. Brit. On rotten wood.

"Plant 1¼ inch high; mycelium white, branched, fibrillose, penetrating into the wood; stem compressed, 1½ line thick, springing from a broader base, divided above into four principal, rather flexuous, slender cylindrical-branches connected at the base, and forked once or twice only; tips very acute. The whole plant is of a pallid ochraceous hue.

"This species is evidently allied to *Clavaria crispula* and *byssiseda.* It agrees more with our common forms of *Clavaria* than those which are peculiar to the Tropics."

Although characters of the spores were not published it is probable that this species might be recognized among Clavarias from Jamaica by the above description, figure, and occurrence on wood. *C. compressa* Schw. has priority.

C. driophylla Rafinesque, Med. Repos. II. 5: 363. 1808; Desvaux, Jour. de Bot. 1: 233. 1808.

"Pédonculée; peridium cylindrique, obtus, jaune.

"En Pensylvanie."

C. fuscescens Fries, R. Soc. Sci. Upsal. Acta III. 1: 116. 1851; Sacc. Syll. Fung. **6**: 714. 1888.

"A basi tenui ramosissima, glabra, pallida, sicca fusca, ramis teretibus solidis multifidis filiformibus laevibus apice subulatis.

"Ad Mirador regni Mexicani ad truncos putridos. Liebman.

"Juxta *C. pyxidatam* videtur inserenda, sed sporae ignotae. Admodum gracilis, 1½ unc. alta, maxime et repetito-ramosa, sed omnes rami filiformes, undique glabri. Sicca mollis et flaccida.

"Similis species lecta (ad terram ?) ad S. Bartolini, Trapede de la conception, colore non diversa, sed ramis intricatis crispulis, ceterum *C. crispulae* simillima."

C. incurvata Morgan, Cincinnati Soc. Nat. Hist. Jour. **11**: 88. *pl. 2. f. 2* 1888; Sacc. Syll. Fung. **11**: 134. 1895.

Plate 11, fig. 101.

"Fragile. Trunk thick, fleshy, white; branches ochraceous,

dichotomously very much branched; the branchlets spreading, somewhat flexuous, rugulose, the apices dentate. See Plate II., Fig. 2.

"On the ground in woods; rare. Trunk white, an inch and a half in height and 1 inch thick; branches and branchlets ochraceous, 2–3 inches longer, with an extent of 3 or 4 inches. The peculiar feature is the spreading branches curving outward and upward."

In the paper cited, Morgan stated that the spores of this species are ochraceous, and he located the species in the group with *C. formosa* and *C. aurea* but did not give dimensions of the spores nor whether even or rough. I have been unable to obtain this needed information, because Professor Wylie kindly informs me that no specimen of *C. incurvata* can be found in Morgan Herbarium, which now belongs to the University of Iowa. On the possibility that Morgan might have given a specimen of the species to Farlow, Peck, or Ellis, I sought in their herbaria for such an authentic specimen but did not find one.

C. lepidorhiza Rafinesque, Med. Repos. II. 1: 362. 1808; Desvaux, Jour. de Bot. 1: 233. 1808.

"En forme de cylindroïde; fistuleuse, rougeâtre; racine et base écailleuse; le sommet arrondi.

"Se trouve en Maryland et près du Hâvre-de-Grâce."

C. molaris Berkeley, Grevillea 7: 5. 1878; Sacc. Syll. Fung. 6: 727. 1888.

"Erumpens, coccinea, apice verrucosa 1. cristata.

"On dead branches of *Magnolia glauca*. Newfield, New Jersey, June, 1873. Ellis. No. 892.

"About a line high, bursting through the bark, scarlet, thickened upwards. Apex either coarsely warty or with a multitude of crest-like processes; spores clavate, acuminate below, .0075 mm., .0003 in. long. Allied to *C. contorta*."

Miss Wakefield could not find the type of this species in Kew Herb.; I have been unable to find it in the Ellis Coll. in N. Y. Bot. Gard. Herb. or in Farlow Herb.

C. polita Fries, R. Soc. Sci. Upsal. Acta III. 1: 116. 1851; Sacc. Syll. Fung. 6: 706. 1888.

"A basi ramosa, glabra, albida, sicca rigido-fragilis, pallescens, ramis fistulosis parce divisis inaequalibus acutis.

"In Mexico ad *Z*uacapa. *Liebman.*

"Habitus peculiaris, politus, fere Corallinae. Caulis a basi solutus in ramos pauciores, parce subdichotomos, teretes 1. in axillis compressos, longitudine inaequales. Sicca polita et nitida est, at colorem non mutat."

C. radiata Léveillé, Ann. Sci. Nat. Bot. III. 5: 156. 1846; Sacc. Syll. Fung. 6: 713. 1888.

"Receptaculis gregariis pedicellatis ramosis, ramis fastigiatis nudis, laevibus elongatis sursum dilatatis margine fimbriatis proliferisque,—Hab. Vera-Cruz (Mexico). Galeotti, n° 6849 (herb. Mus. Par.).

"OBS. Cette Clavaire, comme quelques autres, rappelle le *Cladonia pyxidata;* elle s'élève à la hauteur de 5 à 6 centimètres, et forme un petit buisson plus ou moins épais. Le pédicule, dont la longueur varie de 1 à 2 centimètres, se dilate en forme d'entonnoir à sa partie supérieure, et donne naissance à trois ou quatre rameaux grêles a leur partie inférieure, tandis que la supérieure, également dilatée, est prolifère: ces divisions se répètent ainsi trois ou quatre fois; les dernières seules sont simples et aiguës."

C. sulphurascens Schweinitz, Am. Phil. Soc. Trans. N. S. 4: 182. 1832; Sacc. Syll. Fung. 6: 709. 1888.

"Aestate inter folia putrescentia, Bethl.

"C. delicatula, semiunciali altitudine. Caule aut stipite tereti, basi inerassata, albo-pruinosa; apice ramosa, ramis subfastigiatis teretibus, ramulis breviusculis corniculatis acutis. Radiculis byssoideis foliis insidens. Color totius fungi, e sulphureo-subfuligineus."

I could find no specimen of this species in either Herb. Schweinitz or Curtis Herb.

C. tetragona Schweinitz, Naturforsch. Ges. Leipzig Schrift. 1: 112. 1822; Sacc. Syll. Fung. 6: 708. 1888.

"C. subsimplex fragilis flava, stipite furcato furcisque quadrangularibus.

"Passim autumno ad abrupta umbrosa madida. Substantia

similis Cl. eburneae, unciam sesquialteram alta, tum apice furcata vel bifurcata, etiam in bifurcationibus conservans formam quadrangularem."

I could find no specimen of *C. tetragona* in either Schweinitz Herb. or Curtis Herb.

C. trichomorpha Schweinitz, Naturforsch. Ges. Leipzig Schrift. **1**: 112. 1822; Sacc. Syll. Fung. **6**: 730. 1888.

"C. simplex gregaria candida utrinque attenuata subpellucida.

"Fasciculis densis provenit in caulibus putrescentibus Zeae, in horto deiectis, vere, semunciam longa."

I have found no specimen of *C. trichomorpha* in either Herb. Schweinitz or Curtis Herb.

C. tricolor Rafinesque, Med. Repos. II. **5**: 363. 1808; Desvaux, Jour. de Bot. **1**: 233. 1808.

"Pédonculée; peridium obovale, verdâtre à la base, jaune dans le milieu; sommet rond et rougeâtre.

"Dans l'état de Maryland."

EXCLUDED SPECIES

Calocera albipes (Mont.) Berk. & Curtis, Grevillea **2**: 18. 1873; Sacc. Syll. Fung. **6**: 737. 1888.

Clavaria albipes Montagne, Ann. Sci. Nat. Bot. II. **18**: 244. 1842.

"Gregaria, simplicissima, stricta, clavula utrinquè attenuata apice acuta pallidè rufescens glaberrima, stipite basi dilatatâ candidâ ligno mucido adhaerente.

"Hab. ad lignum semiputridum mucidumque in provinciâ vel statu *Ohio* Americae foederatae a cl. Sullivant lecta mecumque à cl. Asa Gray communicata."

I found no specimen in Curtis Herb. or Farlow Herb.

99. Lachnocladium ornatipes (Peck) Burt, n. comb.

Plate 11, fig. 102.

Clavaria ornatipes Peck, N. Y. State Mus. Bul. **122**: 18, 160. 1908; Sacc. Syll. Fung. **21**: 432. 1912.—*C. trichopus* of Peck, N. Y. State Mus. Rept. **24**: 82. 1872, but not of Persoon.—*Lachnocladium bicolor* of Burt. Mo. Bot. Gard. Ann. **6**: 274.

pl. 5. f. 6, text f. 13. 1920, but not *Clavaria bicolor* Pk.

Type: in N. Y. State Mus. Herb.

"Clubs 1–2 inches tall, gregarious, sparingly branched; stem slender, hairy, fuscous or brown, the branches irregular, terete, whitish, grayish or cinereous, the tips acute or obtuse; spores broadly elliptic or subglobose, .0003–.00045 of an inch long, .00024–.0003 broad.

"In low swampy woods, usually among mosses. Sand Lake.

"In New York State Museum Report 24, page 82 this was referred to Clavaria trichopus Pers. After seeing specimens of it from other localities and finding it constantly differing from the descriptions of that species, which is called "snowy white" and is much branched, it has seemed to us to be distinct."

The spores of the type are hyaline, even, subglobose, 8–9× 7–7½ μ; basidia with 2 sterigmata. Occurs in New Hampshire and Massachusetts also.

100. Lachnocladium subcorticale (Schw.) Burt, n. comb.

Plate 11, fig. 103.

Clavaria subcorticalis Schweinitz, Am. Phil. Soc. Trans. N. S. 4: 182. 1832; Sacc. Syll. Fung. 6: 709. 1888.

Type: in Herb. Schweinitz; no duplicate in Curtis Herb.

"Rarissime sub cortice reperta monte Menango chunk, Jersey.

"C. uncialis, caule brevi tenuori, ramoso-dilatata, ramis subdivaricatim furcatis, compressulis; alutaceo-alba, valde pulverulenta, et subvillosa. Apicibus ramorum acutis. Cornu cervinum aemulat."

The fructification is now between light buff and warm buff, few-branched dichotomously, with the axils rounded, surface clothed with a minutely subtomentose covering of matted fibers. When moistened the texture does not seem fleshy enough for a *Clavaria;* the hyphae are thin-walled, collapsed, about 3 μ in diameter, apparently nodose septate. No basidia found in a preparation and only three spores, two of which are hyaline, rough, 7–9×4½–6 μ and the other, hyaline, even, 9×6 μ. These spores are so few in number that they may not have been borne by this specimen.

As no basidia were found, it may be that *C. subcorticalis* is a *Tremellodendron.* The aspect of this species is so distinctive that future collections should be recognized by the accompanying figure.

101. Lachnocladium vestipes (Peck) Burt, n. comb.

Plate 11, fig. 104.

Clavaria vestipes Peck, N. Y. State Mus. Bul. **116**: 34. 1907.—*C. bicolor* Peck, N. Y. State Mus. Bul. **54**: 954. 1902, but not *C. bicolor* Mass.—*C. Peckii* Sacc. & D. Sacc. in Sacc. Syll. Fung. **17**: 196. 1905, but not *C. Peckii* Sacc. Syll. Fung. **9**: 249. 1901.

Type: in N. Y. State Mus. Herb.

"Small, 8–12 lines high, gregarious; stem slender, .5–1 line thick, straight or flexuous, solid, tomentose, pale yellow, divided above into two or more short, orange colored compressed branches which are themselves once or twice dichotomously divided, tips acute, concolorous.

"Under pine trees. Bolton. September.

"The rather tough tomentose stem indicates an affinity to the genus *Lachnocladium.*"

The hymenial portion is now orange-cinnamon, rugulose and waxy, and the stem chamois-colored, short tomentose in some fructifications and fibrillose in others; spores hyaline, subglobose, 3–4 μ in diameter, becoming distinctly rough. *C. asperula* and *C. asperulans* should be compared with this species.

102. Tremellodendron tenax (Schw.) Burt, n. comb.

Plate 11, figs. 105, 106.

Clavaria tenax Schweinitz, Am. Phil. Soc. Trans. N. S. **4**: 182. 1832.—*Merisma tenax* (Schw.) Léveillé, Ann. Sci. Nat. Bot. III. **5**: 157. 1846.—*Pterula tenax* (Schw.) Sacc. Syll. Fung. **6**: 742. 1888.—*Tremellodendron Hibbardi* Lloyd, Myc. Writ. **6**. Myc. Notes 65: 1049. *pl. 179. f. 1947.* 1921.

Type: in Herb. Schweinitz and a fragment in Curtis Herb.

"Ad terram nudam in Insula Lehigh prope Bethl.

"C. fasciculata, substantia tenacissima, demum subcornea, e basi jam ramoso-divisa, ramis compressis, apice fere in membranam dilatatis, ramulis minutis irregulariter prominentibus et inde fimbriatis. Colore alutaceo-rufo. Uncialem altitudinem non excedit."

Fructifications fascicled with substance very tough, at length somewhat horn-like, soon ramose-divided from the base; branches compressed, dilated at the apex into almost a membrane; branchlets minute, irregularly extended and then fimbriate. Color alutaceous red. Does not exceed an inch in height.

The specimen in Herb. Schweinitz is compressed, not fleshy when moistened, and has the hymenium fuscous; basidia lon-

gitudinally septate; spores hyaline, even, flattened on one side, 9×5½ μ.

A specimen of *Tremellodendron Hibbardi*, fig. 106, collected by Miss Hibbard at West Roxbury, Mass.—the type locality—agrees well with the original specimen of *Clavaria tenax*, fig. 105. *T. tenax* has somewhat the aspect of some forms of *T. pallidum* but is readily separable from the latter by the very dark hymenium of *T. tenax*.

Clavaria gigantea Schweinitz, Naturforsch. Ges. Leipzig Schrift. **1**: 113. 1822; Am. Phil. Soc. Trans. N. S. **4**: 182. 1832; Fries, Elenchus Fung. **1**: 231. 1828 . Plate 11, fig. 107.

Acurtis gigantea (Schw.) Fries, Summa Veg. Scand. 337. 1849; Sacc. Syll. Fung. **6**: 691. 1888; **11**: 139. 1895; Cooke, Grevillea **20**: 11. 1891; Berkeley, Gardeners' Chron. **9**: 339. 1878.

Type: authentic specimen from Herb. Schweinitz now in Curtis Herb.; no specimen in Herb. Schweinitz.

"C. caespitosa carnosa, clavis difformibus compressis contortis substriatis maximis albo-testaceis.

"Septembri et Octobri. Caespites ad radices arborum et in terra efformat magnitudine capitis humani, fungus omnino abnormis, quibusdam annis frequens, aliis rarissimus. Ex una radice, subradiculosa oriuntur clavae interdum regulares, ad sex uncias latae, unam vel tres uncias altae et unciam crassae; substantia carnosa et fibrosa agaricina, odore muscoso Agarici Prunuli. Interdum clavae solitariae occurrunt. Quandoque pulvere albo detergibili tegitur."

Present-day collections of this fungus would not be referred to the *Clavariaceae*, for very careful examination of preparations of the outer surface of the fructifications of the authentic specimens does not show basidia nor any distinctive spores or fruiting organs by which the fungus may be classified. I did not find any evidence that these pyriform masses are Agarics overrun by a *Hypomyces*. European mycologists have found in Europe malformations of *Lentinus tigrinus* of such form that they so regard *"Clavaria gigantea."* In the Eastern United States *Clitopilus abortivus* may form in great abundance malformations very similar in aspect and consistency to the specimens of *"Clavaria gigantea"* which have been preserved; it is my opinion that the latter was based on such abortive growths. The note by Schweinitz of odor of *Agaricus* [*Clitopilus*] *prunulus* favors this conclusion also.

Craterellus pistillaris Fr.—See Burt, Mo. Bot. Gard. Ann. **1**: 341. *pl. 16, 17, f. 13, 14.* 1914.

Clavaria truncata Lovejoy, Bot. Gaz. **50**: 385. 1910.

"Pileate tops bright red, shading into reddish orange at top of stipe to dull flesh color at its base: ends truncate, convex to plane to somewhat concave, 0.5–3 cm. broad, smooth: whole plant to within a few centimeters of base of stipe covered with a white bloom, persisting in dried specimens: flesh creamy, spongy: stipe longitudinally grooved to base, 3–10 cm. long: spores white, 14×7 μ.

"Habitat: Humus soil under balsam and spruce trees; gregarious and cespitose, 4–6 in a group; Foxpark, alt. 2900 meters, August 8, 1909, no. 66.

"A plant similar to this is described by Fries as *Craterellus pistillaris* and by others as possibly a variety of *Clavaria pistillaris,* but in a collection of twenty specimens found in entirely different localities not one out of the number was found to have either the color or the form of typical *Clavaria pistillaris.*"

I have not seen authentic specimens of *C. truncata* but its description, quoted above, shows that *C. truncata* is a synonym of *Craterellus pistillaris* and extends the American range of the latter to the Rocky Mountain region.

103. Pistillaria Typhuloides (Peck) Burt, n. comb.

Plate 11, fig. 108.

Clavaria Typhuloides Peck, N. Y. State Mus. Rept. **30**:49. *pl. 2. f. 12–14.* 1878; Sacc. Syll. Fung. **6**: 731. 1888.

Type: in N. Y. State Mus. Herb.

"Very small, about two lines high, rather tough, scattered or gregarious, clavate, white, the stem slightly pruinose, gradually swelling into the obtuse glabrous subcompressed solid club; spores oblong-elliptical, .0002′–.0003′ long, with an oblique point at the base.

"Dead stems of *Epilobium angustifolium.* Adirondack. August.

"This belongs to the section Holocoryne, and is apparently allied to *C. uncialis,* but its much smaller size and usually compressed club will serve to distinguish it. When dry the white color is well retained and the hymenium has a subpellucid appearance and is of a firmer texture than the center of the club."

The dried fructifications are now clavate, with the hymenial region cream-buff and the stem whitish; basidia simple but I cannot decide from reexamination of my preparation in glycerine

medium as to whether only 2-spored; spores hyaline, even, slightly curved, 5–6×2½ μ, copious. The hyphae have the outer portion of the wall gelatinously modified and the center of the club, which Peck noted as not as firm in texture as the hymenium, has become very hard in the dried clubs and did not soften after moderately prolonged moistening.

EXOTIC SPECIES

104. Clavaria decolor Berk. & Curtis, Am. Acad. Arts & Sci. Proc. 4: 124. 1858; Sacc. Syll. Fung. 6: 712. 1888.
Plate 11, fig. 109.

Type: specimen from type collection in Farlow Herb.

"Ex albo umbrina; stipite cylindrico e fibris ramosis oriundo sursum subdichotomo, ramis brevibus.

"On hill-sides, Hong Kong. - Allied to *C. abietina.*"

The earth at base of the fructifications shows that they grew on the ground. The collector's note with the specimen is "In dense thickets on hillsides, Hong Kong. White soon turning brown or black."

The fructifications are now between drab and hair-brown; spores hyaline, minutely rough, globose, 3–4×3 μ, numerous but none seen attached to basidia, and possibly foreign, because the specimens are mouldy.

105. C. delicia Berkeley, Hooker's Jour. Bot. 8: 274. 1856; Sacc. Syll. Fung. 6: 710. 1888. Plate 11, fig. 110.

Lachnocladium delicia (Berk.) Cooke, Grevillea 20: 10. 1891.

Type: probably in Kew Herb., a specimen from the type collection in Curtis Herb.

"Ochracea, caespitosa, delicata; stipitibus brevibus cylindricis e mycelio candido membranaceo oriundis, ramis furcatis hic illic divergentibus, ultimis acutissimis. Spruce, n. 161.

"Hab. On dead leaves and twigs. March, 1853. Panuré. [Brazil].

"Ochraceous, about half an inch high, forming delicate, tree-like tufts. Stems short, cylindrical, clothed at the base with a little down, and arising from a white, downy, membranous disc, forked two or three times, some of the branches spreading so as to form little tree-like tufts; ultimate ramuli very acute.

"An extremely pretty species, with the habit of *C. flaccida,* but approaching in substance the white-branched *Thelephorae,*

though more transparent. At first sight it has somewhat the appearance of *T. dissecta,* Lév., a very differently constructed species."

Fructifications now pinkish buff with whitish mycelium at the base; spores hyaline, even, globose, 4–5 μ in diameter.

106. C. delicata Fries, Syst. Myc. 1: 475. 1821; Hym. Eur. 670. 1874; Sacc. Syll. Fung. **6**:699. 1888. Plate 11, fig. 111.

Type: authentic specimen from Fries, collected at Upsala, Sweden, in Curtis Herb.

"Tenella, e basi ramosa, candida, deorsum villosa, ramis gracilibus, elongatis, teretibus, aequalibus, erectis, acutis . . . . . Ad ligna mucida Fagi. Eximia."

Fructification now sorghum-brown to Rood's brown, somewhat rugose, attached to the wood by a whitish mycelial base; spores hyaline, even, somewhat curved, 5–6×2½ μ. This fructification is not on *Fagus* but on coniferous wood, for the wood substratum consists of tracheids with bordered pits.

107. C. scabra Berkeley, Hooker's Jour. Bot. 8: 277. 1856; Sacc. Syll. Fung. **6**: 728. 1888. Plate 11, fig. 112.

Type: probably in Kew Herb., a specimen from the type collection in Curtis Herb.

"Simplex umbrina acuminata pusilla scabra; basi tuberosa, setis erectis strigosa. Spruce, n. 157.

"Hab. On the ground. Panuré. [Brazil].

"About 1/3 of an inch high, gregarious, subcaespitose, pale umber, simple, erect, acuminate, scabrous with little rough granules; base tuberose, clothed with white or pallid, erect bristles.

"This is in many respects like *Calocera tuberosa,* but it appears to be a true *Clavaria,* and is distinguished by its smaller size, scabrous hymenium, and the erect or slightly divergent, not deflexed, bristles at the base.—There is another simple *Clavaria* in the collection, growing on a green substance, which appears to be an anamorphosis of some Lichen. The specimens are however too imperfect to afford much information."

The fructifications have dried resin color (somewhat cinnamon) with the base whitish; spores not certainly made out in my preparation, possibly minute, even, subglobose, 1½–2 μ in diameter.

108. C. cirrhata Berkeley, Hooker's Jour. Bot. 8: 275. *pl. 5. f. 5.* 1856; Sacc. Syll. Fung. **6**: 708. Plate 11, fig. 113.

Type: authentic specimen in Curtis Herb.

"Caespitosa, alba, ramosa; ramis suberectis cylindricis, apicibus rectis curvatisque acutis.

"Hab. On the ground. Mount Cocui. [Brazil].

"Two inches high, ochraceous, white, caespitose, much branched; branches cylindrical, tips straight or curved.

"This was first referred as a variety to *Clavaria furcellata,* but this indication is untenable, and I have therefore described it under a distinct name."

Instead of being only 2 inches high as published, the dried fructification is twice that height, or 9½ cm., as shown by the accompanying illustration which is natural size. The hymenial regions are now cartridge-buff and the stem and sterile branch portions pinkish buff and fibrillose-squamulose; the axile tissue of stem and branches is somewhat colored; spores hyaline, even, globose, 5–6 μ in diameter.

The consistency of the moistened fructification seems to me too firm and tough for *Clavaria* and I believe that this species will be transferred to *Lachnocladium,* when its characters are better known from the study of specimens in fresh condition. Perhaps the South American *Lachnocladium cirratum* or one of Hennings' Brazilian species may prove identical with Berkeley's *C. cirrhata.*

109. Lachnocladium dealbatum (Berk.) Cooke, Grevillea **20**: 10. 1901. Plate 11, fig. 114.

Clavaria dealbata Berkeley, Hooker's Jour. Bot. 8: 275. 1856; Sacc. Syll. Fung. **6**: 707. 1888.

Type: specimen from the type collection in Curtis Herb.

"Caespitosa, alba, opaca; stipite brevi tenui cylindrico sursum 5–6-furcato ramis dilatatis, apicibus subuncinatis acutis. Spruce, n. 159.

"Hab. On the ground. March, 1853. Panuré. [Brazil].

"White, opaque, 2 inches or more high, caespitose, fastigiate. Stem short, cylindrical, not a line thick, forked five or six times so as to make a tree-like tuft, dilated above, the ultimate divisions somewhat divaricate, the forks below acute, above rounded, ultimate ramuli acute.

"A very singular species, remarkable for its white-washed appearance. The branches, except at the extremities, are far

broader than the stem, and strongly compressed when dry. Spruce compares this with n. 601, [*Stereum proliferum*], but the two species do not appear to me to have much in common."

Main stem and branches now olive-buff and the terminal branchlets pinkish cinnamon (resinous); spores hyaline, echinulate, 3½–4×2½–3 μ, copious. I found only one branch broader than the stem, while several branches are of the same diameter as the main stem. The consistency of the substance when moistened is such that the transfer to *Lachnocladium* seems probably correct.

INDEX TO SPECIES OF CLAVARIA.

	Page
abietina	20
acris	23
albida	18
albipes	65
amethystina	41
amethystinoides	42
arborea	30
Ardenia	59
argillaceae	53
asperula	33
asperulans	34
asperulospora	60
asterella	37
aurantio-cinnabarina	43
aurea	13
Berkeleyi	61
bicolor	61
bicolor	67
biformis	51
botrytis	7
botrytoides	8
brunneola	25
cervicornis	24
chionea	29
cinerea	40
cinereoides	40
circinans	27
cirrhata	72
citriceps	56
citrina	61
citrino-fusca	61
clara	56
clavata	55
compressa	44
compressa	62
conjuncta	9
contorta	60
corniculata	38
coronata	35
corynoides	54
crassipes	19
cristata	31
cyanocephala	16
dealbata	72
delicata	71
delicia	70
decolor	70
densa	14
densissima	14
divaricata	37
driophylla	62
ericetorum	54
exigua	42
fellea	39
filipes	53
fistulosa	59
flaccida	26
flava	12
flavella	57
flavobrunnescens	22
flavula	21
flavuloides	28
foetida	52
formosa	11
fragilis	48
fragrantissima	28
fumigata	15
fuscescens	62
fusiformis	44
gigantea	68
gracillima	54
gracilis	28
grandis	15
Herveyi	39
holorubella	10
inaequalis	55
incurvata	62

	Page
juncea	60
Krombholzii	32
Kunzei	29
laeticolor	57
lavendula	47
lentofragilis	37
lepidorhiza	63
leucotephra	21
ligula	58
longicaulis	17
Macouni	45
misella	49
molaris	63
mucida	50
mucida var. Curtisii	50
muscoides	38
muscoides var. obtusa	39
mutans	31
myceliosa	29
nebulosa	47
nodulosperma	34
obtusissima	11
ornatipes	65
pallescens	46
Peckii	38
Peckii	67
Petersii	35
pilipes	59
pilosa	46
pinicola	25
pinophila	36
pistillaris	58
pistillaris umbonata	58
platyclada	45
polita	63
pulchra	57
pusilla	27
pyxidata	34
radiata	64
rufipes	33
rugosa	32
scabra	71
Schaefferi	48
secunda	19
similis	38, 56
spathulata	53
sphaerospora	52
spiculospora	17
stricta	23
stricta var. *fumida*	23
subcaespitosa	30
subcorticalis	66
subfalcata	51
subtilis	28
sulphurascens	64
tenax	67
tenuis	49
testaceoflava var. testaceoviridis	20
tetragona	64
trichomorpha	65
tricolor	65
truncata	69
tsugina	24
Typhuloides	69
vermicularis	48
vernalis	55
vestipes	67
xanthosperma	18

Explanation of Plates

PLATE 1

All figures of plates 1 to 11 have been reproduced natural size from photographs of dried herbarium specimens unless otherwise noted.

Fig. 1. *Clavaria botrytis.* After the figure in Fries, Sverig. Atl. Svamp., *pl. 35.*

Fig. 2. *C. botrytoides.* Type.

Fig. 3. *C. conjuncta.* Type.

Fig. 4. *C. secunda.* Type.

Fig. 5. *C. densissima.* Type.

PLATE 2

Fig. 6. *C. holorubella.* Type.

Fig. 7. *C. formosa.* After the figure in Persoon, Icones et Descr. Fung., *pl. 3. f. 5.*

Fig. 8. *C. longicaulis.* Type.

Fig. 9. *C. densa.* Type.

Fig. 10. *C. fumigata.* Type.

Fig. 11. *C. spiculospora.* After Atkinson's photograph of the type.

PLATE 3

Fig. 12. *C. aurea.* After Schaeffer, Icones Fung., *pl. 287, f. 4,* under the name *C. flavescens,* a synonym of *C. aurea* and with the better illustration.

Fig. 13. *C. grandis.* Type.

Fig. 14. *C. cyanocephala.* Type.

Fig. 15. *C. xanthosperma.* Type.

Fig. 16. *C. albida.* Type.

Fig. 17. *C. testaceoflava* var. *testaceoviridis.* Type.

PLATE 4

Fig. 18. *C. obtusissima.* Type.

Fig. 19. *C. flava.* After Schaeffer, Icones Fung., *pl. 175, f. 2.*

Fig. 20. *C. flavula.* Type.

Fig. 21. *C. leucotephra.* Type.

Fig. 22. *C. flavobrunnescens.* Type.

Fig. 23. *C. stricta.* After the figure in Persoon, Comment Clav., *pl. 4. f. 1.*

Fig. 24. *C. brunneola.* Specimen in Wright, Fungi Cubenses Wrightiani, 462, which I compared with the type and preferred for the illustration.

Fig. 25. *C. flaccida.* After Fries, Icones Hym., *pl. 199. f. 4.*

Fig. 26. *C. flaccida.* Specimen from Fries in Curtis Herb., collected at Upsala, Sweden.

Fig. 27. *C. pusilla.* Type.

PLATE 5

Fig. 28. *C. abietina.* After Fl. Dan., *pl. 2030. f. 2.*
Fig. 29. *C. stricta* var. *fumida.* Type.
Fig. 30. *C. acris.* Type.
Fig. 31. *C. tsugina.* Authentic specimen, probably type.
Fig. 32. *C. pinicola.* Type.
Fig. 33. *C. circinans.* Type.
Fig. 34. *C. flavuloides.* Type.
Fig. 35. *C. fragrantissima.* Type.
Fig. 36. *C. Kunzei.* After Quelet, Champ. Jura et Vosges **3:** *pl. 2. f. 11.*

PLATE 6

Fig. 37. *C. myceliosa.* Type.
Fig. 38. *C. arborea.* Type.
Fig. 39. *C. subcaespitosa.* Type.
Fig. 40. *C. cristata.* After Holmskiold, Fungi Dan., *pl. 23*—three figures.
Fig. 41. *C. mutans.* Type.
Fig. 42. *C. rugosa.* After Bulliard, Herb. de la France, *pl. 448. f. 2.*—two of the six fructifications.
Fig. 43. *C. rufipes.* Type.
Fig. 44. *C. asperula.* Three cited specimens, each marked "Part of type."
Fig. 45. *C. asperulans.* Type.
Fig. 46. *C. nodulospora.* Type.
Fig. 47. *C. pyxidata.* After Persoon, Comment. Clav., *pl. 1. f. 1a.*
Fig. 48. *C. Petersii.* Type distribution.

PLATE 7

Fig. 49. *C. coronata.* Type.
Fig. 50. *C. pinophila.* Type.
Fig. 51. *C. crassipes.* Half of type, which had been split lengthways.
Fig. 52. *C. asterella.* Type.
Fig. 53. *C. divaricata.* Type.
Fig. 54. *C. lentofragilis.* Type.
Fig. 55. *C. corniculata.* After Schaeffer, Icones Fung., *pl. 173. f. 6, 9.*
Fig. 56. *C. Peckii.* Type.
Fig. 57. *C. muscoides* var. *obtusa.* Type.
Fig. 58. *C. fellea.* Type.
Fig. 59. *C. Herveyi.* Type.

PLATE 8

Fig. 60. *C. cinerea.* After Bulliard, Herb. de la France, *pl. 354.*
Fig. 61. *C. cinereoides.* Type.

Fig. 62. *C. amethystina.* After Battarra, Fung. Agri Arim., *pl. 1. f. C.*
Fig. 63. *C. amethystinoides.* Type.
Fig. 64. *C. exigua.* Type.
Fig. 65. *C. aurantio-cinnabarina.* Type.
Fig. 66. *C. fusiformis.* After Sowerby, Brit. Fungi., *pl. 234.*
Fig. 67. *C. compressa.* Type.
Fig. 68. *C. platyclada.* Type.
Fig. 69. *C. Macouni.* Type.
Fig. 70. *C. pilosa.* Type.
Fig. 71. *C. pallescens.* Type.
Fig. 72. *C. nebulosa.* Type collection.

PLATE 9

Fig. 73. *C. lavendula.* Type.
Fig. 74. *C. vermicularis.* After Holmskiold. Fungi Dan. 1: *pl. 2. f.* at right.
Fig. 75. *C. tenuis.* Type.
Fig. 76. *C. misella.* Type collection.
Fig. 77. *C. mucida.* After Persoon. Comment. Clav.: *pl. 2. f. 3.*
Fig. 78. *C. mucida* var. *Curtisii.* Type, No. 655.
Fig. 79. *C. biformis.* Type, consisting of Nos. 13432 and 10699.
Fig. 80. *C. subfalcata.* Type.
Fig. 81. *C. foetida.* Type.
Fig. 82. *C. sphaerospora.* Type; best, selected clubs.
Fig. 83. *C. filipes.* After tracing of type.
Fig. 84. *C. spathulata.* Type.
Fig. 85. *C. argillacea.* After Boudier., Icones, *pl. 175. f. a.*
Fig. 86. *C. corynoides.* Type.
Fig. 87. *C. gracillima.* One club of type.
Fig. 88. C. *vernalis.* Collected at Sharon, Mass., May 24, 1917, by A. P. D. Piguet, comm. by W. G. Farlow.
Fig. 89. *C. inaequalis.* After Fl. Dan., *pl. 836. f. l.* (left hand part).

PLATE 10

Fig. 90. *C. citriceps.* Type.
Fig. 91. *C. clara.* Type.
Fig. 92. *C. laetico'or.* Three clubs of type collection, *C. Wright, 226,* compared with type. The clubs of the type are now broken.
Fig. 93. *C. pulchra.* Type.
Fig. 94. *C. flavella.* From type collection, compared by me with type.
Fig. 95. *C. ligula.* After Schaeffer, Icones Fung., *pl. 171. f. 1.*
Fig. 96. *C. fistulosa.* After Holmskiold, Fungi Dan. 1: *pl. 6.* (right hand part).
Fig. 97. *C. contorta.* After Holmskiold, Fungi Dan. 1: *pl. 12.* (right hand part).
Fig. 98. *C. juncea.* After Boudier, Icones, *pl. 176. f. b.*
Fig. 99. *C. asperulospora.* Type.
Fig. 100. *C. compressa* Berk. After Berkeley, Ann. & Mag. Nat. Hist. 10: *pl. 12. f. 16.* Nat. size.

PLATE 11

Fig. 101. *C. incurvata.* After Morgan, Cincinnati Soc. Nat. Hist. Jour. **11:** *pl. 2. f. 2.*

Fig. 102. *Lachnocladium ornatipes.* Type of *Clavaria ornatipes.*

Fig. 103. *L. subcorticale.* Type of *Clavaria subcorticalis.*

Fig. 104. *L. vestipes.* Type of *Clavaria vestipes.*

Figs. 105 and 106. *Tremellodendron tenax.* Fig. 105, type of *Clavaria tenax;* fig. 106, specimen of *Tremellodendron Hibbardi* collected in Massachusetts by Miss A. Hibbard.

Fig. 107. *Clavaria gigantea.* Authentic specimen in Curtis Herb. from Herb. Schweinitz.

Fig. 108. *Pistillaria Typhuloides.* Type of *Clavaria Typhuloides.*

Fig. 109. *Clavaria decolor.* Type.

Fig. 110. *C. delicia.* Authentic specimen, *Spruce, No. 161,* in Curtis Herb.

Fig. 111. *C. delicata.* Authentic specimen in Curtis Herb.

Fig. 112. *C. scabra.* Authentic specimen, *Spruce, No. 157,* in Curtis Herb.

Fig. 113. *C. cirrhata.* Authentic specimen in Curtis Herb.

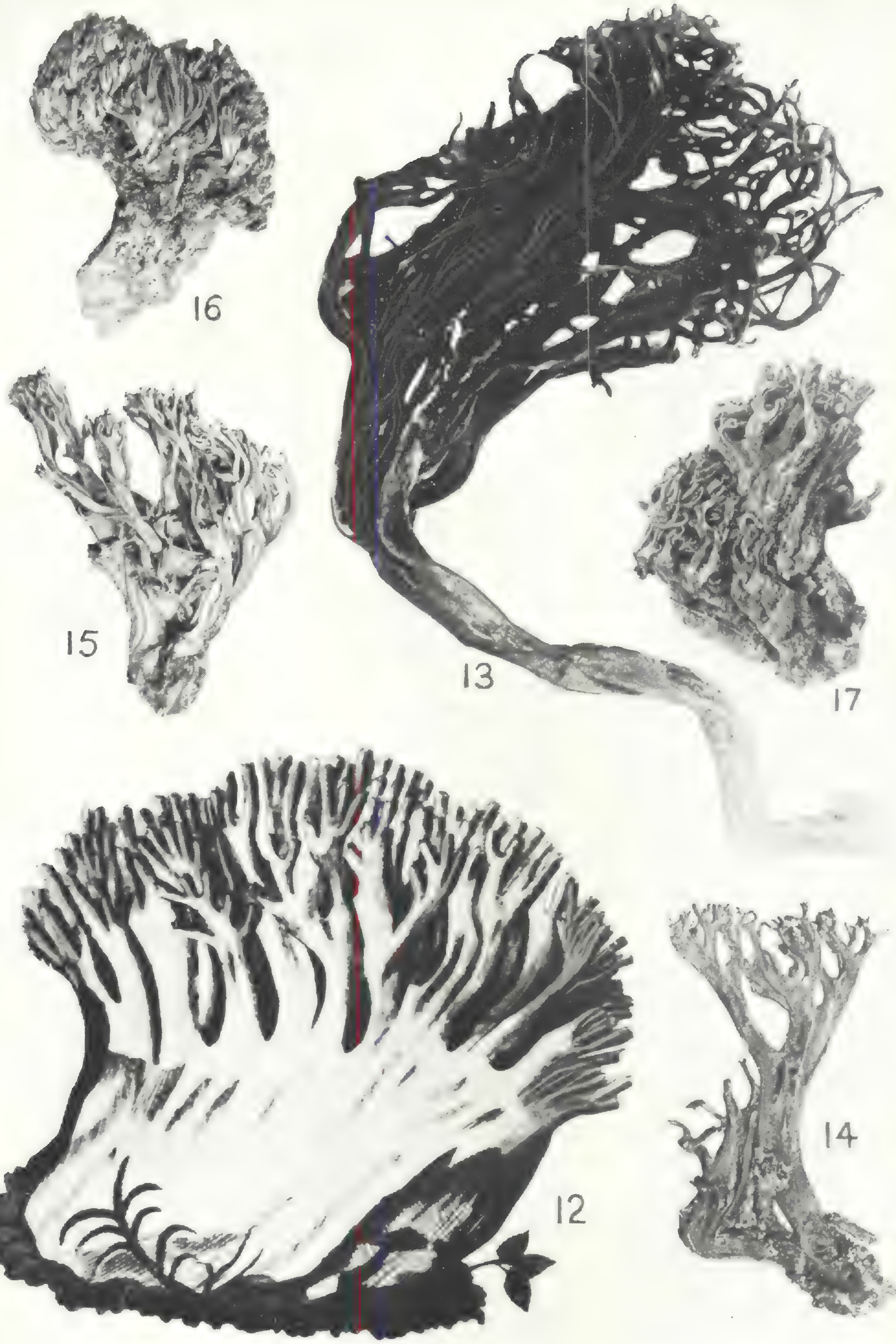
Fig. 114. *Lachnocladium dealbatum.* Authentic specimen, *Spruce, No. 159,* of *Clavaria dealbata* in Curtis Herb.

BURT—THE NORTH AMERICAN SPECIES OF CLAVARIA

1. CLAVARIA BOTRYTIS.—2. C. BOTRYTOIDES.—3. C. CONJUNCTA.—4. C. SECUNDA.—5. C. DENSISSIMA

BURT—THE NORTH AMERICAN SPECIES OF CLAVARIA

6. CLAVARIA HOLORUBELLA.—7. C. FORMOSA.—8. C. LONGICAULIS.—9. C. DENSA.—10. C. FUMIGATA.—11. C. SPICULOSPORA

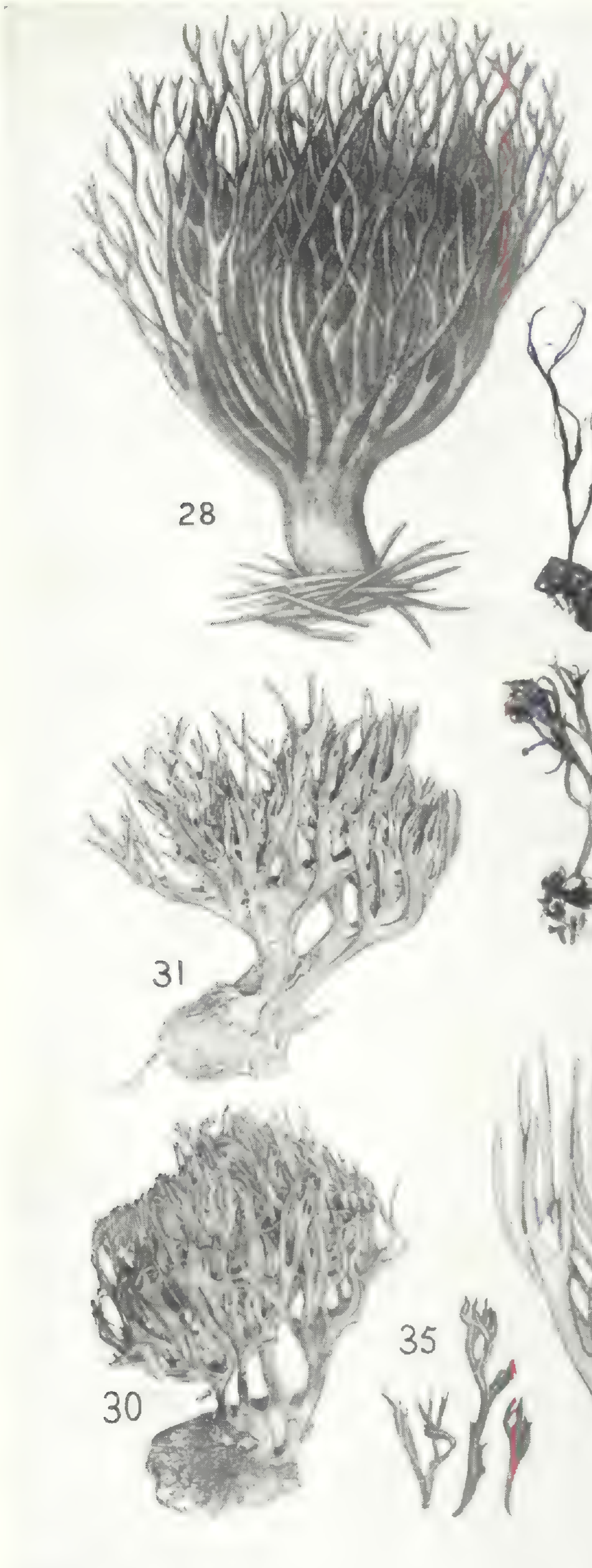


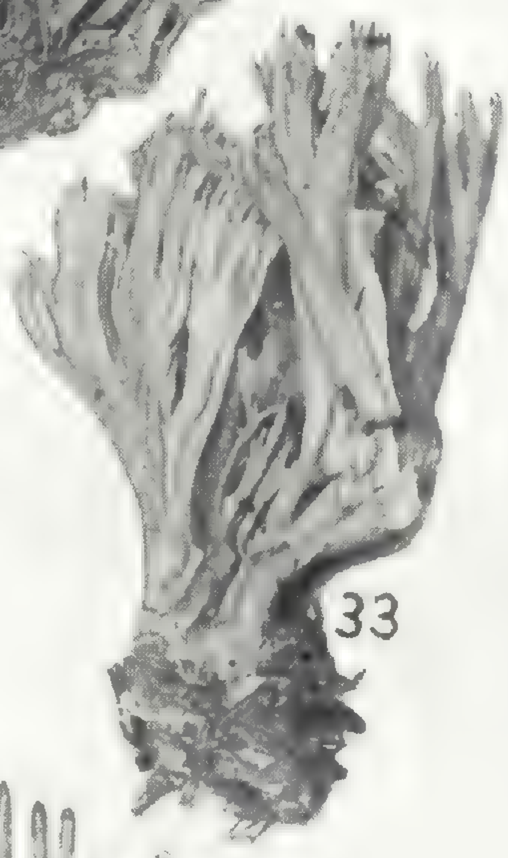
BURT—THE NORTH AMERICAN SPECIES OF CLAVARIA

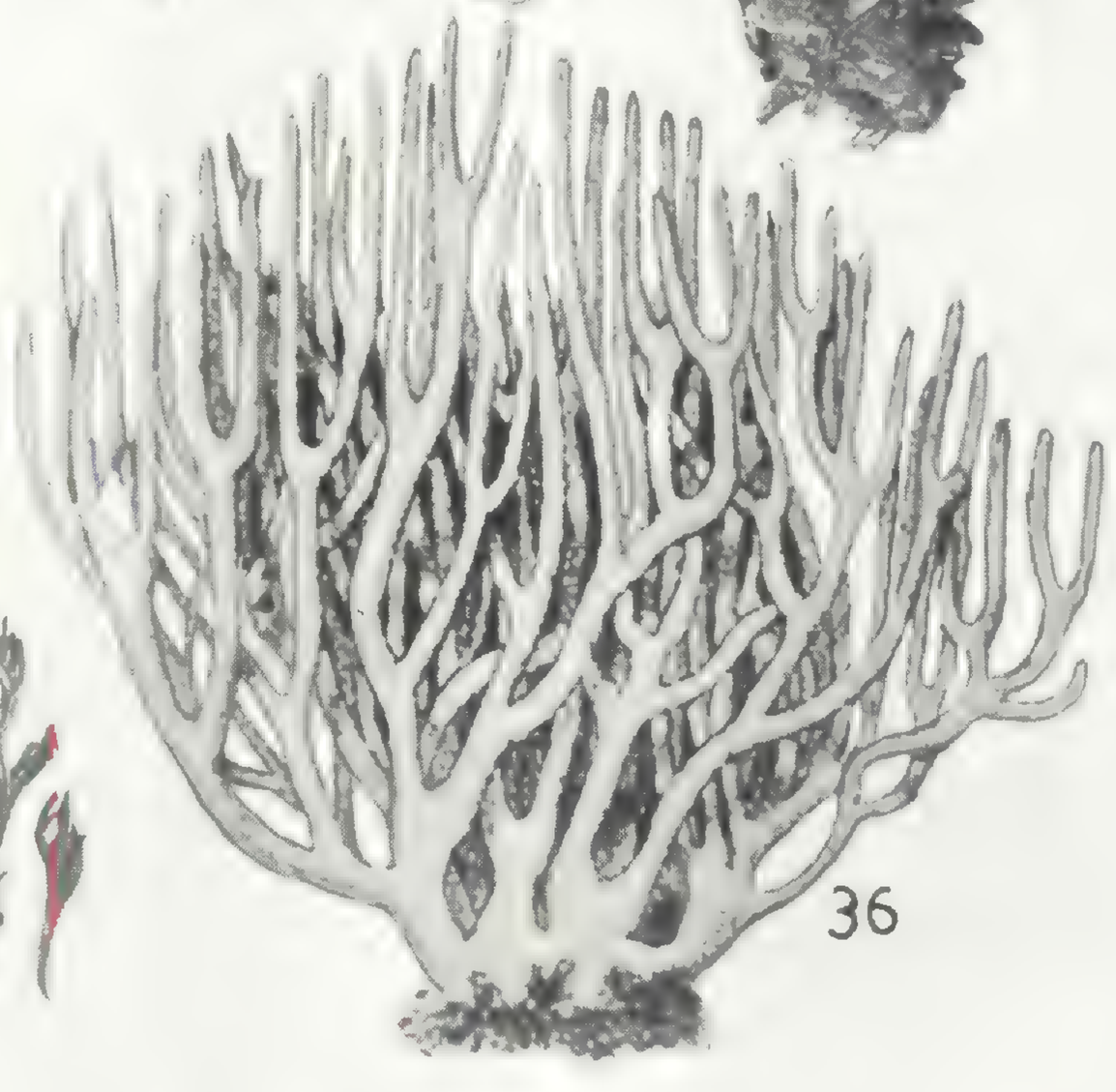
12. CLAVARIA AUREA.—13. C. GRANDIS.—14. C. CYANOCEPHALA.—15. C. XANTHOSPERMA.—16. C. ALBIDA.—17. C. TESTACEOFLAVA VAR. TESTACEOVIRIDIS

BURT—THE NORTH AMERICAN SPECIES OF CLAVARIA

18. CLAVARIA OBTUSISSIMA.—19. C. FLAVA.—20. C. FLAVULA.—21. C. LEUCOTEPHRA.—22. C. FLAVO-BRUNNESCENS.—23. C. STRICTA.—24. C. BRUNNEOLA.—25. C. FLACCIDA.—26. C. FLACCIDA.—27. C. PUSILLA

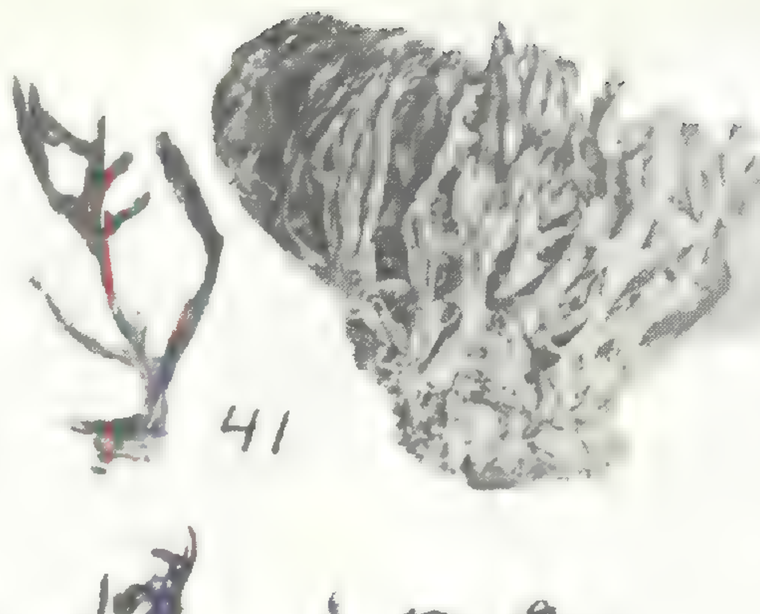


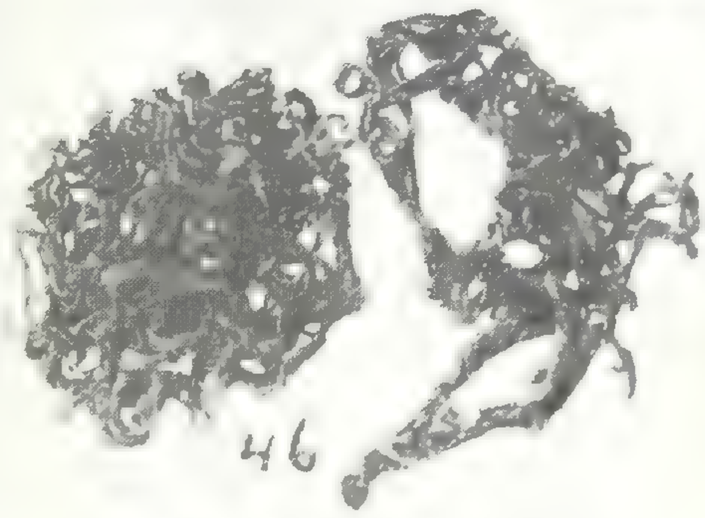




BURT—THE NORTH AMERICAN SPECIES OF CLAVARIA

28. CLAVARIA ABIETINA.—29. C. STRICTA VAR. FUMIDA.—30. C. ACRIS.—31. C. TSUGINA.—32. C. PINICOLA.—33. C. CIRCINANS.—34. C. FLAVULOIDES.—35. C. FRAGRANTISSIMA.—36. C. KUNZEI





BURT—THE NORTH AMERICAN SPECIES OF CLAVARIA

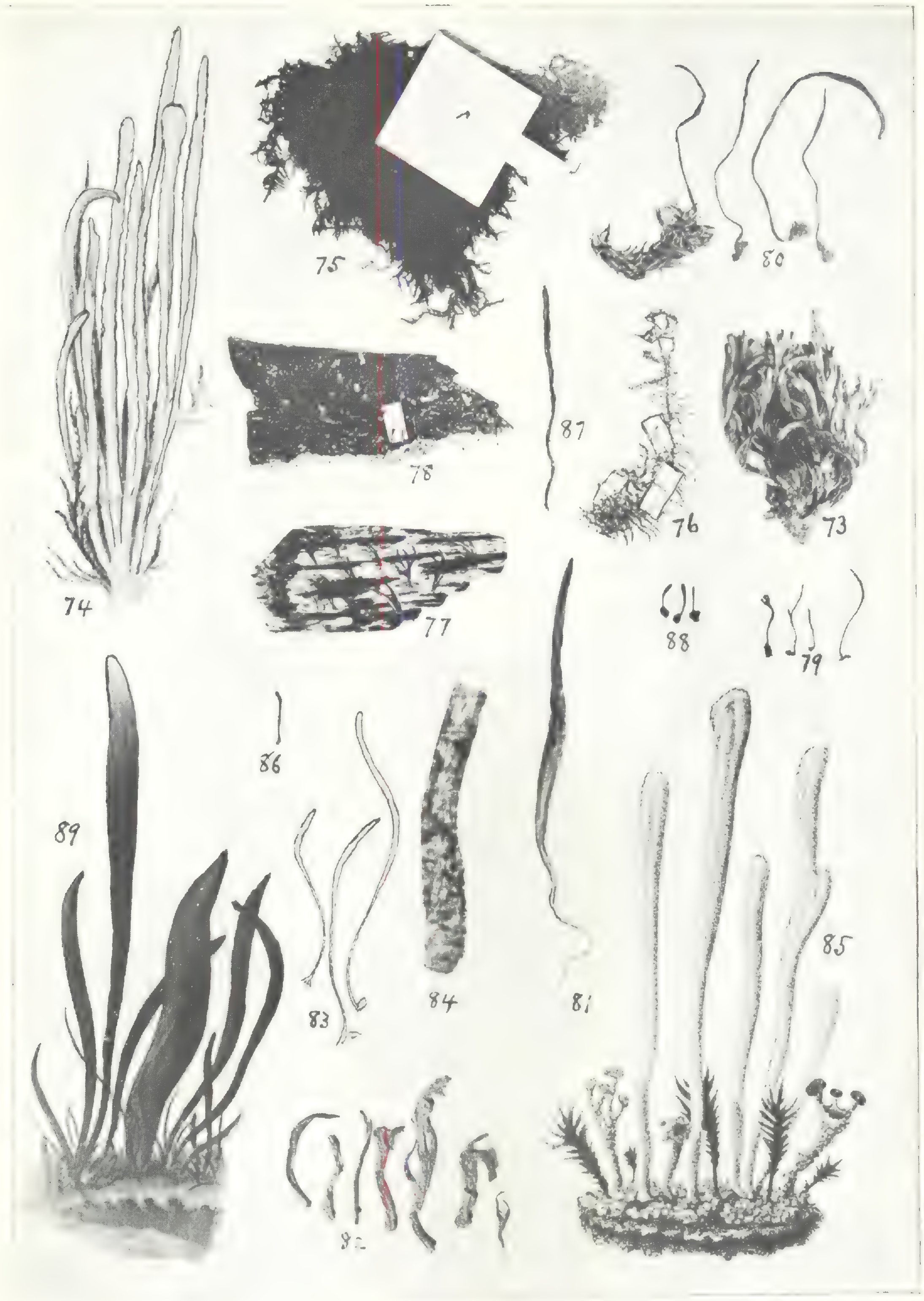
37. CLAVARIA MYCELIOSA.—38. C. ARBOREA.—39. C. SUBCAESPITOSA.—40. C. CRISTATA.—41. C. MUTANS.—42. C. RUGOSA.—43. C. RUFIPES.—44. C. ASPERULA.—45. C. ASPERULANS.—46. C. NODULOSPORA.—47. C. PYXIDATA.—48. C. PETERSII

BURT—THE NORTH AMERICAN SPECIES OF CLAVARIA

49. CLAVARIA CORONATA.—50. C. PINOPHILA.—51. C. CRASSIPES.—52. C. ASTERELLA.—53. C. DIVARICATA.—54. C. LENTOFRAGILIS.—55. C. CORNICULATA.—56. C. PECKII.—57. C. MUSCOIDES VAR. OBTUSA.—58. C. FELLEA.—59. C. HERVEYI

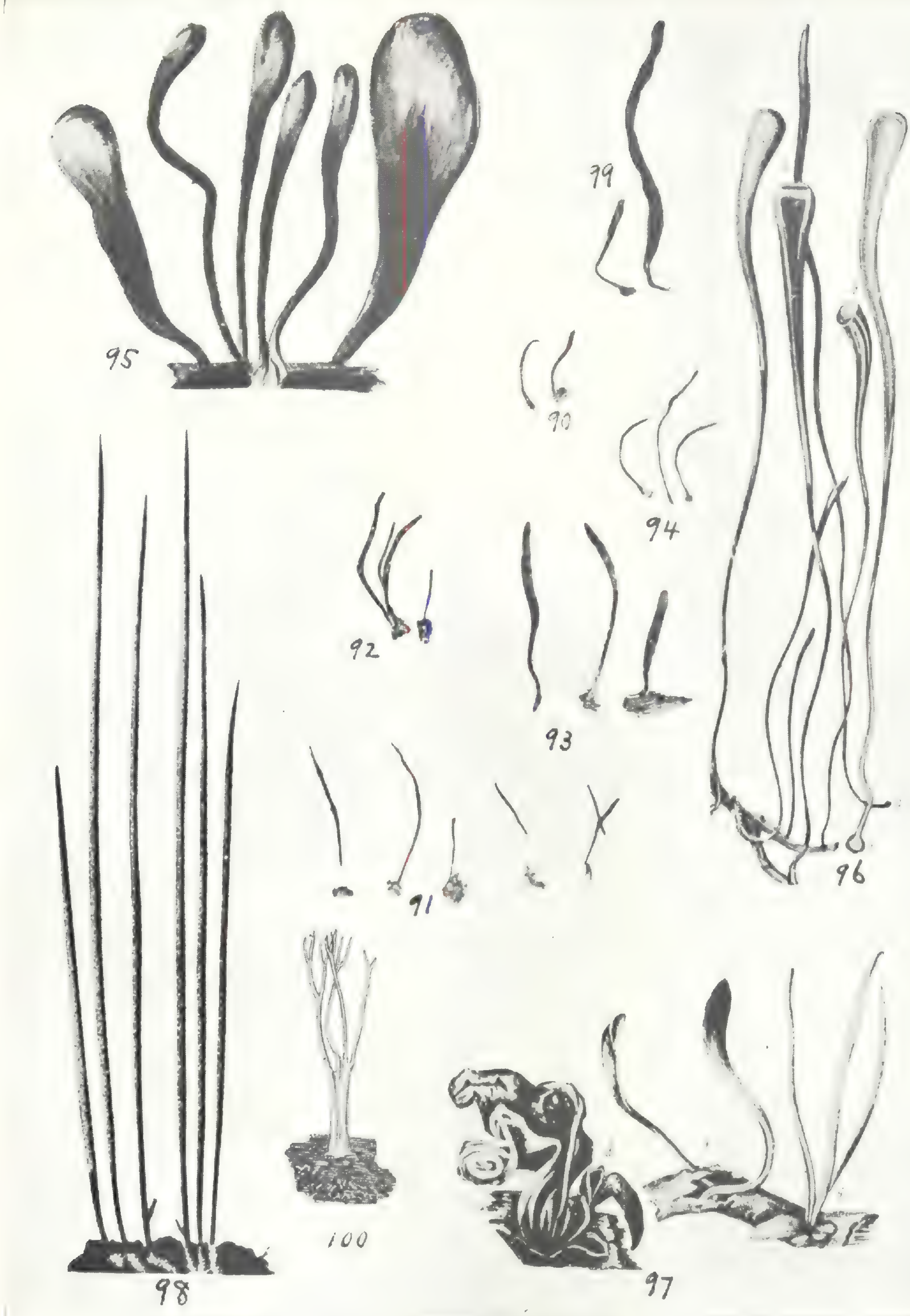
BURT—THE NORTH AMERICAN SPECIES OF CLAVARIA

60. CLAVARIA CINEREA.—61. C. CINEREOIDES.—62. C. AMETHYSTINA.—63. C. AMETHYSTINOIDES.—64. C. EXIGUA.—65. C. AURANTIO-CINNABARINA.—66. C. FUSIFORMIS.—67. C. COMPRESSA.—68. C. PLATYCLADA.—69. C. MACOUNI.—70. C. PILOSA.—71. C. PALLESCENS.—72. C. NEBULOSA



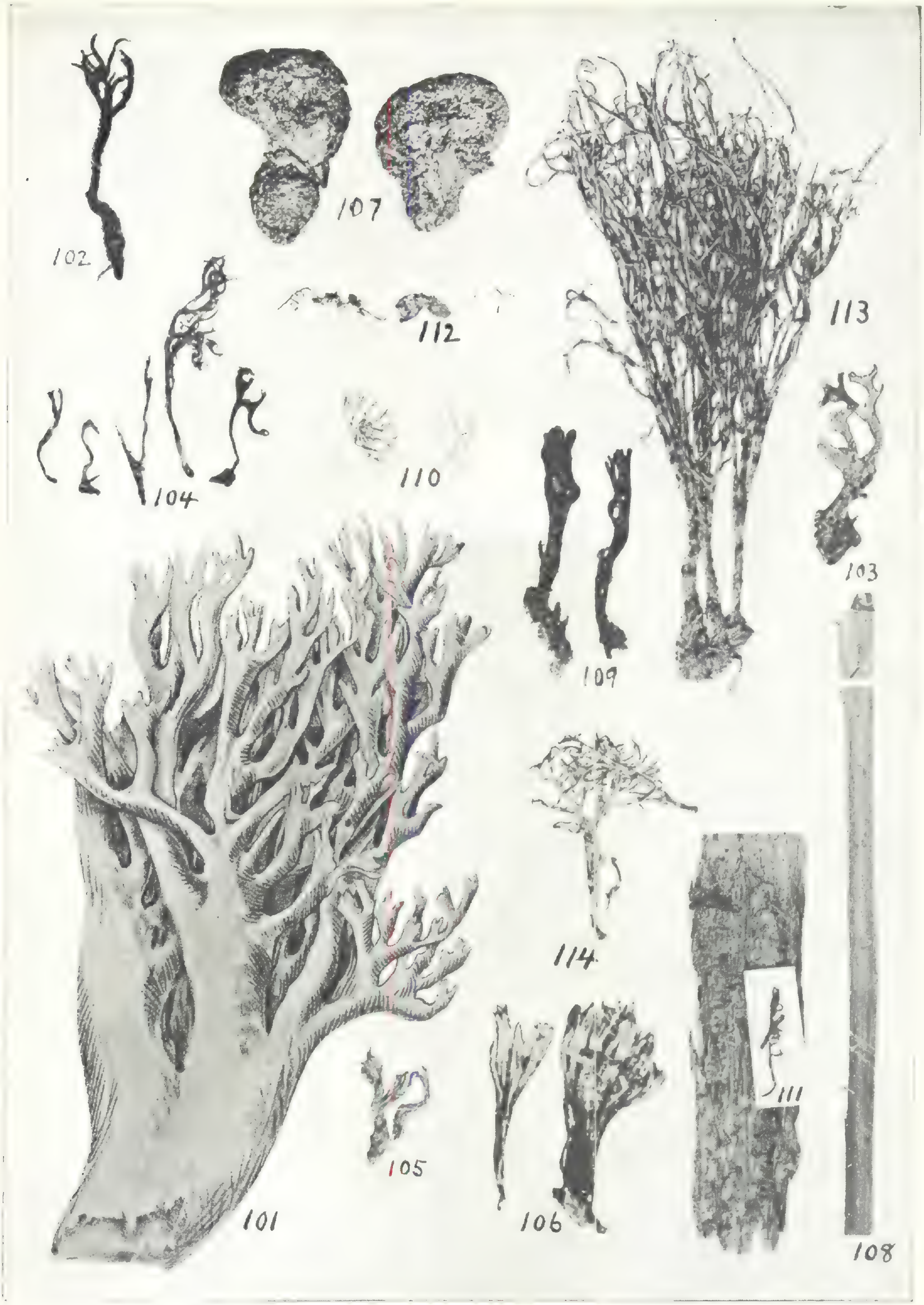
BURT—THE NORTH AMERICAN SPECIES OF CLAVARIA

73. CLAVARIA LAVENDULA.—74. C. VERMICULARIS.—75. C. TENUIS.—76. C. MISELLA.—77. C. MUCIDA.—78. C. MUCIDA VAR. CURTISII.—79. C. BIFORMIS.—80. C. SUBFALCATA.—81. C. FOETIDA.—82. C. SPHAEROSPORA.—83. C. FILIPES.—84. C. SPATHULATA.—85. C. ARGILLACEA.—86. C. CORYNOIDES.—87. C. GRACILLIMA.—88. C. VERNALIS.—89. C. INAEQUALIS



BURT—THE NORTH AMERICAN SPECIES OF CLAVARIA

90. CLAVARIA CITRICEPS.—91. C. CLARA.—92. C. LAETICOLOR.—93. C. PULCHRA.—94. C. FLAVELLA.—95. C. LIGULA.—96. C. FISTULOSA.—97. C. CONTORTA.—98. C. JUNCEA.—99. C. ASPERULOSPORA.—100. C. COMPRESSA



BURT—THE NORTH AMERICAN SPECIES OF CLAVARIA

101. CLAVARIA INCURVATA.—102. LACHNOCLADIUM ORNATIPES.—103. L. SUBCORTICALE.—104. L. VESTIPES.—105 106.—TREMELLODENDRON TENAX.—107. CLAVARIA GIGANTEA.—108. PISTILLARIA TYPHULOIDES.—109. CLAVARIA DECOLOR.—110. C. DELICIA.—111. C. DELICATA.—112. C. SCABRA.—113. C. CIRRHATA.—114. LACHNOCLADIUM DEALBATUM

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MONOGRAPH OF THE ISOETACEAE[1]

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History

The name *Isoetes* was first mentioned by Linnaeus in 1751 (Skanska Resa, 417, fig. 1), although the common European species of the group had been previously known for many years and variously recorded under different names. In 1753 Linnaeus (Species Plantarum 2: 1100) definitely established the genus *Isoetes,* as follows:

> "*lacustris.* ISOETES. *It. Scan.* 417. *t.* 419. *Nov. gen.* 1109. Marsilea foliis subulatis semicylindricis articulatis. *Fl. suec.* 996. [Stockholm, 1745].
> Calamaria folio longiore & graciliore. *Dill. musc.* 541. *t.* 80. *f.* 2. [Oxford, 1741].
> Subularia lacustris f. Calamistrum herba aquatica alpina. *Raj. angl.* 1. *p.* 210. *t.* 210. [London, 1677].
> *Habitat in* Europae *frigidae fundo lacuum.*"

In the following year Linnaeus (Genera Plantarum, 486. 1754) characterized the genus, relating the structures to those of seed plants. The male flowers were described as solitary within a base of inner leaves, with no corolla, but with a calyx of cordate scales, acute and sessile, and with stamens having subrotund, unilocular anthers, but no filaments. The female flowers were reported as solitary, within a base of outer leaves of the same plant, with the calyx and corolla situation as in the male. The pistil was described as having an ovate embryo within a leaf, but the style and stigma were supposed to be hidden. The fruit was considered to be a capsule, subovate and bilocular, concealed in the base of the leaf, and the seeds to be numerous and globose. In an earlier account (Skanska Resa, 417. fig. 1. 1751), Linnaeus expressed jubilation over finding flowers, whereas Dillenius had seen only fruits.

[1]Special investigation carried on mainly at the Missouri Botanical Garden.

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Crude as is the description of Linnaeus, it surpassed the earlier accounts. Ray, who provided the earliest account, credited D. Lloyd with finding the material in an alpine lake, and remarked that "of this plant, one sees nought but leaves and roots, and knows not from what source it comes directly."

Dillenius developed a little greater detail in regard to the structure. He described two plants, similar in their fleshy tubers, but differing in the shorter, coarser, incurved leaves of the one, and the finer, longer, erect leaves of the other. The latter, considered synonymous with *I. lacustris* L., is described as having "a root harder than a leek, less tuberous, less thick," but otherwise having the same texture of leaf, color, seeds, etc. In the description of the short-leaved form, the channels in the leaf and the transverse septa are brought out as they are in the diagrams of the fine-leaved plants. The plants are reported as growing "in great abundance in very long, deep ponds near Llanberry" and in mountain lakes.

Scarcely more enlightening is the account of the next species of *Isoetes* to be recorded. In 1781, *I. coromandelina,* similar to *I. lacustris* L., but larger, was reported by Linnaeus fil. as growing in wet places, submerged in the rainy season, in Coromandel. Attention in the description is chiefly drawn to the filiform, erect, glabrous character of the leaves and the broadened membranaceous leaf-bases which form the bulbous portion of the plant.

The first detailed account of the development of *Isoetes* occurs in connection with the description of a third species, *I. setacea,* by Delile[1] in 1827. He carefully observed the life-history through the seasons, and as a result laid a better morphological basis than his predecessors. A comparison is made with *Lycopodium* but the author decides that *Isoetes* resembles the lily or *Juncus* more in its embryo characters. However, the genus is finally placed between *Marsilea* and *Lycopodium*, with interpretations of all structures made on the basis of seed-plants.

The following year H. G. L. Reichenbach published the first account in which the family name for *Isoetes* is used, here as *Isoeteae.* This, or similar forms, as *Isoetineae,* is used by all the subsequent workers cited up to the paper of Underwood, where the modern *Isoetaceae* is used for the first time. There is a good deal of confusion in the references given by some of

[1]Delile, A. R. Examen de la vegetation de l' Isoetes setacea et exposition de ses caractères. Mus. Paris Mem. **14**: 110–119. *pl. 6–7.* 1827.

the earlier authors, as, for example, Schnizlein, who credits Bartling as the originator of the family name in the text and Richard in the legend on the plate illustrating his paper.

References occur twice which suggest that Claude Richard was responsible for the idea of a separate family containing the *Isoetes* species. Delile himself in 1827 places the genus between *Lycopodium* and *Marsilea*, but says that Richard believes it a family distinct from *Lycopodium* and other ferns. Again, in 1844, we have the statement of Bory that Claude Richard believes that *Isoetes* ought to be considered as a separate family from other ferns. It has been impossible to find any account published by Richard himself in regard to this point.

Within a short interval after Delile's work on *I. setacea* Bosc, much interest was stimulated in the genus through the work of two investigators, A. Braun and Durieu de Maisonneuve. The former developed not only systematic, but much morphological, knowledge in regard to various species. The latter was chiefly instrumental in augmenting systematic information, especially in regard to Algerian species.

In 1867, Milde[1] brought together forms that occur within a relatively much larger territory than had been previously considered. An idea may be obtained of the various contributions, especially of Braun and Durieu, from the fact that by this time the number of species within the range of Milde's work is 15.

A synopsis of the species of *Isoetes* was published within a little over a decade by Baker[2], who later incorporated the same manuscript with little additional material in his 'Fern Allies'. In this synopsis, 46 species are brought together by the author whose primary divisions are on the basis of geography.

Following Baker's work, Motelay and Vendryès[3] monographed the genus, including 47 species. The work is enhanced by the illustrations which include those of many spore forms. Not a few of the forms considered in Baker's synopsis and in the monograph by Motelay and Vendryès were due to the activity of Engelmann.[4]

[1]Milde, J. Filices Europae et Atlanticis, Asiae minoris et Siberiae, 274–290. 1867.

[2]Baker, J. G. A synopsis of the species of Isoetes. Jour. Bot. **18**: 65–70, 105–110. 1880, and Fern Allies, 123–134. 1887.

[3]Motelay, L. et Vendryès. Monographie des Isoëteae. Soc. Linn. de Bordeaux, Actes **36**: 309–405. *pl. 8–17*. 1883.

[4]Engelmann, G. The genus Isoëtes in North America. St. Louis Acad. Sci., Trans. **4**: 358–389.1882.

In 1882, in a systematic treatment, he considered the North American forms to the number of 15 species with their varieties. The contribution is of exceptional value as an account of the genus and includes an excellent treatment of the history of the genus in this country.

Almost simultaneously with this work appeared Underwood's[1] publication in which he first used the modern form of family termination in *Isoetaceae*. A lucid account of 14 forms in North America is supplemented with good generalizations on the distribution of forms.

Within more recent years, there has been no outstanding addition to our systematic knowledge of the family through the activity of European investigators. In America, there has been a material increase in information, especially concerning the representatives on the eastern border, through the work of Dodge[2] and Eaton.[3] These authors, as is true of most of their predecessors, published less comprehensive studies in various journals.

In a less technical consideration of the family, Clute[4] has recently recognized 21 species in the United States. This represents the latest account of the genus as a whole in America. There have, however, been treatments over more restricted ranges in various manuals and floras. The more important of these are cited in connection with the systematic treatment of the family, and therefore require no further consideration here.

Local Names and Economic Uses

The first popular name recorded for *Isoetes* is that given by Dillenius in 1741, where "quillwort" and "Merllyn's Grass" are cited. That the former name has survived is well known to us in America, and Clute[5] is authority for the statement that *Isoetes lacustris* is still called Merlin's grass in northern Europe.

Linnaeus in 'Skanska Resa' reports that the natives refer to *Isoetes* as "Brachsen grass." Ascherson and Graebner (Syn. Mitteleur. Fl. 1: 163. 1896-98) give the following: "Brachsenkraut: dän: Brasenurt: poln: Poryblin. böhm. Sédlatka."

[1]Underwood, L. M. Our Native Ferns and Fern Allies, 121. 1882.
[2]Dodge, R. Ferns and Fern Allies of New England. 1896.
[3]Eaton, A. A. The Genus Isoetes in New England. Fernwort Papers. 1900.
[4]Clute, W. N. The Fern Allies, 209–254. 1905.
[5]Clute, W. N. *loc. cit.* p. 224.

The technical name for the genus seems to be in common use. By derivation, it indicates the evergreen character of at least some of the species "equal at all seasons of the year" or throughout the year, from ἴσος, equal, and ἔτος, year. Some forms are, however, false to the name in that no leaves, sterile or otherwise, seem to survive the winter or dry season. The perennial character of the corm is not to be doubted in such plants though the leaves do disappear.

In the older accounts, it is of interest that an economic relation was usually mentioned. So Ray (1696) says that the plant "gives out a melancholy fluid, used in affections of the spleen and liver. It is accredited somehow with sharing the habit of the plants with which it grows." Dillenius, on the other hand, cites as its use that the plant is eaten by fish.

That birds are not disinterested in the food use of *Isoetes* is evidenced by the story of Durieu, who first saw *I. histrix* bulbs under rather unusual circumstances.[1] The peculiar organs were found in the stomach of a bird which was shot down by a member of his party. The real nature of the plant structures was only recognized in subsequent field work when similar bulbs were discovered growing on the hillsides of Algeria. That a terrestrial form resembling this Algerian plant, *I. Duriaei,* is eagerly devoured by pigs, is also quoted from the statements of Bory de Saint-Vincent.

In the eastern United States, one observer says that ducks are fond of the bulbs or sporangia masses at the base of the plant and will tweak them off, allowing the leaves to float. Clute says of *I. Braunii* Dur. that the crisp bulbs are favorite morsels with muskrats, and that cattle are said to feed upon the leaves of any species available.

The corms are said to have been eaten occasionally in Europe by human beings, though the taste is variously described as earthy and unpalatable (Clute) or acid and bad-tasting (Delile). Undoubtedly the presence of starch and oil give the spores and corms food value, whether they be palatable or not. The distribution hardly seems extensive enough to make consideration of development of a taste for them worthy of attention. The plants probably are of greatest economic use at present as a source of food for the lower animals mentioned.

[1]Bory de Saint-Vincent, Sur les Isoëtes et les espèces nouvelles de cette famille decouvertes en Algerie. Compt. Rend. Acad. Paris **18**: 1167. 1844.

General Morphology

The genus limits of *Isoetes* are very sharp and clear, so that there is no difficulty in recognizing a member within it. However, sections within the genus prove more difficult of discovery and definition. In the past, much emphasis has been laid by systematic workers in this field on the relations to water. Engelmann used the subdivisions "submersed, amphibious, and terrestrial" as his primary subdivisions. Motelay and Vendryès used two main headings, thus:

I. Aquaticae
- Submersae
- Palustres
- Amphibiae

II. Terrestres

It has seemed that the ecological relations might not be adequate as bases for primary divisions of the genus. The attempt has therefore been made to utilize more constant features of a morphological character. It seemed that the spore characters, related as they are to fruiting rather than to vegetative stages, might prove more consistent. It has been found that the megaspores, especially, run fairly constant in size and markings. In conjunction with these spore characters, it is necessary for safety in classification to take into consideration other features, such as the velum, which proves fairly dependable as a character, the lobing of the plant corm, usually a reliable feature, and other less constant characters like the ligule and the presence and number of peripheral strands of supporting tissue in the leaf. These features are considered in greater detail in the subdivision which follows, i. e., morphology.

In the genus the habit of the body is definitely characteristic and easily recognized in perfect specimens. The stem portion is unusually compact, both vertically and horizontally, and gives rise to a group of rush-like leaves in crowded spiral formation, and to many dichotomously-branched roots.

Stripped of its leaves and roots, the perennial stem is readily seen to have two or three more or less deep furrows, which result in producing a two- or three-lobed body. The number of lobes so produced is characteristic of the species concerned, save in the rare cases where three lobes may be found in a usually bilobed form or four in a trilobed. The roots appear chiefly in the fur-

rows, somewhat obscuring the real form of the stem in many cases.

The upper portion of the stem or corm is flattish or concave; in growth, the central lowest part gives rise to the newest leaves, while the successively older ones are pushed out to the periphery by the newer growth. There is no apical cell responsible for stem growth, according to Farmer ('90), although according to the evidence seen by Scott and Hill ('00) there may be one.

Anatomically, the compact stem has proved an interesting problem. The vascular cells are centrally located in a single group, which has been interpreted either merely as a union of the leaf-traces (Hegelmaier, '72) or as a small distinct stem stele plus the leaf-traces (Scott and Hill, '00).

Although the xylem character of the tracheids in this central region seems clear, there has been much discussion as to the significance of the zone immediately about it, the so-called "prismatic layer." According to Russow ('72) and Scott and Hill ('00) this undoubtedly contains distinct phloem elements. According to Farmer ('90), Wilson-Smith ('00), and Stokey ('09), the phloem interpretation is invalid, because of the inability to identify sieve structures here. The last-named worker sees only xylem cells as representatives of conducting tissues in this region.

A meristematic zone adds new tissue to the prismatic layer and to the outer parenchyma region. The latter, cortex in nature and position, usually dies at the margin, and in time is sloughed off, although the accumulation of dead cells may be appreciable before being worn off. This is especially true in terrestrial forms where the leaf bases are persistent and the dead cortex remains in place over successive seasons. More frequently, however, the wearing away tends to balance in part the increase in diameter, so that even very old stems are not excessive in size.

The roots are interesting in that they branch dichotomously. In anatomy, they are peculiar in being collateral endarch. The vascular bundle upon emergence from the central stele is surrounded by parenchyma which is replaced by a small group of phloem cells on the side away from the axis of the stem (Stokey, '09).

In the early growth of the sporophyte and before sporophyll production in each growing season, sterile leaves are usually produced. These are similar to the fertile leaves or sporophylls

which appear later except for the absence of the sporangium.

The leaves consist of two regions, a long narrow extension widening into a sheathing base, the margins of which are membranaceous in character. The lateral extension of the base and the longitudinal extension of the transparent edges may serve in some degree as diagnostic characters, though there is variation according to the size of the plant, position of the leaf, and especially the depth of the corm in the soil.

On the upper or inner face, each leaf bears a delicate little extension of tissue, free end uppermost, lying parallel to the leaf surface. This ligule in face view appears most often triangular, sometimes much elongated, sometimes subulate or rounded. To some extent, the form and size of the ligule may prove of value in diagnosis, though not constant enough to be of determining caliber. Especially in older leaves, it may be imperfect through tearing of the delicate tissue. The ligule was called the "calyx" by Linnaeus, and "processus glandulae" by Cesati and DeNotaris ('58). The former interpretation may be understood in view of the attempt to homologize structures in *Isoetes* with those in flowering plants. The latter term is clear when one sees the swollen imbedded portion of the ligule, called the "glossopodium" by A. Braun ('64). This, in section, is sharply distinguishable from the adjacent tissues of the leaf, though intimately grown to them, and might readily be compared to a glandular structure.

Wilson-Smith further terms the layer of large glandular cells about the glossopodium and next the leaf tissues proper the "sheath" and distinguishes between the dead marginal and apical cells, and the living central region of the tongue-like extension of the ligule.

The origin of the ligule has been shown to be a single superficial cell (Hofmeister, '62, and Wilson-Smith, '00) of the leaf, which develops very rapidly to form a short row of cells, soon becoming a plate, except in the basal portion which, as indicated above, becomes massive.

The insertion of the ligule is sometimes marked by a fold of tissue immediately below the base, to which Braun applied the name "labium". This is apt to be fairly consistent in the degree of development within the species, but is so small a character that it is difficult to use it in a diagnostic fashion.

In early stages of leaf development, the ligule is longer than the leaf, which is originally a low rudiment, soon developing into an elongated structure with a broader base. The latter develops more rapidly at first both in size and differentiation; later the distal portion exhibits greater growth, resulting in the elongated part above the ligule. In this region, there occur four long air-channels, intersected at intervals by transverse partitions. The cavities are produced while the upper part of the leaf is still meristematic. Groups of cells lose their contents, the cells break apart through solution of the pectins of the middle lamella, a process followed by disintegration of cells while intervening patches fail to change and so form the septa. The continued growth of the living cells at the periphery brings about increase in length and width of the cavities between these diaphragms.

At the center of the leaf in the tissue between the channels, the single collateral vascular bundle is located. Peripherally, in the layers of green tissue, may occur strands of supporting or mechanical tissue, which have commonly been called "peripheral bast." Since there seems to be no reason for assigning a conducting function to the thick-walled cells in these groups, the term peripheral strands is here substituted for bast. By far the most common distribution of these strands is that in which there is one at each side angle of the adaxial face and one each at the adaxial and abaxial ends of the middle partition. When six groups are present, the other two are at the ends of the cross-partition. Any accessory strands produced are not usually so well developed as these six.

In leaves which are fertile, the sporangia occur singly at the base, on the inner face of the leaf. At maturity, each sporangium appears to be fitted into an elongated or round cavity, termed the "fovea" by Braun. From the margins except at the base there may be a fine, one-celled layer of tissue, the velum, extending over the sporangium to a greater or less degree. Within limits, the degree of development of this velum may be useful as a diagnostic feature. Some forms characteristically show no velum formation, as *Isoetes Malinverniana;* in *I. Engelmanni,* the velum is usually narrow but evident; in *I. Orcuttii,* it is complete, covering the sporangium all the way to the base. In the form *I. Braunii,* the American ally of *I. echinospora* Dur. it varies from 1/3 to 2/3, or occasionally even more extended.

Where the sporangium wall is exposed, it, as well as the adjacent epidermal tissue of the leaf base, may show wall thickening in groups of cells, resulting in a brown-spotted effect under magnification. When the patches of brown sclerenchymatous cells are very numerous, the brown coloring is readily noted; an extreme case is found in *I. melanopoda* Gay & Dur., where the specific name is derived from the deep coloring of the bases of the leaves.

The sporangia are of two sorts, occurring in the same plant, though in some cases at different seasons. A striking example of probable difference in time is found in the East Indian form. The description of *I. coromandelina* L. fil. and *I. brachyglossa* A. Br. both left the condition of the microspores and microsporangia in doubt because of the failure to obtain microsporangiate material. In a collection sent from India through the courtesy of Dr. W. S. Dudgeon, all the sporangia appeared to be megasporangiate. Yet with diligent search about the bases, among old megaspores, microspores, probably from the previous season, were found.

The sporangia of the two kinds have been found to originate and pass through their early stages in similar fashion (Bower, '08, Wilson-Smith, '00). It is only in later development, and especially at maturity, that the heterosporous nature becomes striking. The sporangium initial is a transverse row of superficial cells, which by periclinal divisions, give rise to wall layers and to a sporogenous mass. The velum may be derived from a part or the whole of the upper tier of cells arising from the division of the initial cells (Wilson-Smith, '00). According to the results of Scott and Hill, the velum arises from the tissue between the ligule and the sporangium initial. The growth here in the "sella," a term given by A. Braun, first gives the labium by upward growth, and then the velum by downward extension.

Bands of cells in the sporogenous region become sterile, forming the trabeculae, eventually more or less plate-like cross extensions into the spore mass, bordered by a tapetal layer (Wilson-Smith). The trabeculae are unusually large and distinct in the megasporangia, in which some of the potentially sporogenous cells develop at the expense of others. The large functional ones produce tetrads of megaspores, whereas in the microsporangia, all the sporogenous mass, except the trabecular strips, produces microspores.

The group of microspores from a mother cell may show bilateral or tetrahedral arrangement. In either event, the freeing of the spores soon allows the loss of the sharpness of the original form, so that the microspore is more or less rounded at the two side angles, though with a sharper angle on the third side, parallel to the long axis. Usually the long diameter of the microspores will fall between 20 and 40 μ, with the width or thickness less than 25 μ. In some forms, there are markings of the exospore, resulting in papillose or spinulose effects. More rarely, there may be the development of a wing extension or crest, especially on the side opposite the sharp angle. There is little variation in coloring in the microspores, which are generally ashy, fawn, or cinnamon-brown. As diagnostic features, the microspore size, primarily, and markings and coloring, secondarily, may be used to advantage.

The study of the megaspores has many advantages over that of microspores. Their greater size, due to the functioning of fewer cells in the sporangium at the expense of other potentially sporogenous cells, makes for facility in handling. The size varies in the species between 250 and 900 μ in general, with a much smaller range in the individual species. The coloring of the megaspores in most cases is white or gray-white but in cases of exceptions, as the black in *I. melanospora* Engelm., the color is a useful diagnostic character. Most important are the markings or sculpturing on the surface of the siliceous exospore. The spores, formed in tetrahedral groups, retain the impression of their three neighbors on three faces, which are separated by rounded or sharp ridges which converge at the apex (sometimes called commissural ridges). The fourth face of each spore, originally the free surface in the tetrad, is hemispherical or but slightly flattened, and is separated from the three more nearly plane faces by the ridge called the "equator."

The sculpturing, consisting of spines, of small tubercles or warts, or of reticulate markings, may be similar on all faces, or may differ from the other three on the fourth or basal side. These characters within the species seem as conservative features as occur in *Isoetes* and therefore of great value diagnostically.

The sporangia in *Isoetes* lack a definite device for dehiscence, and hence both types of spores are released only upon decay of the sporangium walls. As a result, there is an accumulation of

the spores about the bases of the still active leaves, from which material for study of the gametophyte stages may be drawn.

The microspore upon germination gives rise to a small lenticular cell at one end, which has been called the prothallial cell. The remaining cell, the antheridium initial, divides in such fashion that a single wall-layer is formed, investing a central region of four cells, each one of which produces a large multiciliate, spirally coiled sperm (Belajeff, '85).

The megaspores, well filled with storage material of starch and oil, are reported by Campbell ('91) as undergoing free nuclear division to the number of 30–50 nuclei, when division walls begin to appear at the apical end, later along the margin of the spore, and eventually in the central portion. There is some increase in size with development, as a rule, so that there is cracking along the three ridges converging at the apex. It is in this region that the archegonia develop, so that three lines of these up to the number of thirty can be observed, if fertilization is prevented. According to Campbell, the archegonium initial divides transversely, giving rise to the cover cell (later producing four tiers of neck cells) and the inner cell (later dividing into the neck canal and the central cell). The neck canal nucleus divides, but according to Campbell, no wall is produced and it remains a short wide cell. In other species, a longitudinal wall has been reported by Miss Lyon and Arnoldi. The central cell divides to produce an egg and a ventral canal cell quite as broad as the egg.

When mature, the archegonium shows the usual canal to the egg, due to disintegration of the canal cells, which allows the entrance of sperms and the subsequent fertilization of the egg. In the development of the embryo, the first stage (Campbell) is transverse division into two cells, followed by a quadrant stage in the most regular cases. The two lower quadrants are reported as giving rise to the foot, one of the upper to a leaf and one to a root. Later, a stem tip develops between the leaf base and the root, in such manner that its origin may be from either. Very early in the development of the leaf rudiment, the ligule cell begins its activity. Division of cells and elongation is rapid in all regions, so that the stages pass quickly. The embryo sporophyte soon projects beyond the gametophyte, a second leaf is formed and a second root. Meanwhile, there is tissue differentiation; the vascular elements of the leaf, stem, and root are

distinct, and the air-channels (only two in the first leaves) are produced.

After development of sterile leaves for a few seasons, the sporophyte begins to produce sporangia, as previously noted.

Apogamy has been reported by only one worker, Goebel ('97), who found examples in *I. lacustris* L. and *I. echinospora* Dur. where the tiny leaf-producing shoots eventually giving rise to roots replaced sporangia in position. These plantlets became independent by the decay of the old leaf tissue.

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Ecological Relations of the Genus Isoetes

The genus *Isoetes* presents interesting ecological and geographical relations. The species prove very diverse in habitat, ranging from lacustrine forms submerged in five or more feet of water, to those strikingly xerophytic, exposed on dry hillsides. Structural characters appear unusually constant, save in minor points. Plants are perennial, and in some cases seem able to withstand desiccation over long intervals, appearing after one or

more dry seasons. Still others grow where alternately submerged and exposed during each growing season.

Ecologically, therefore, it is convenient to subdivide the group into (1) submersed, (2) amphibious, and (3) terrestrial forms, though this does not represent systematic relations.

The geographic range of the individual species is usually limited, but representatives of the genus are found in practically all explored countries. In Europe, France leads with five species; in Africa, Algeria with four species and one variety. In North America, Massachusetts with five species has probably more recorded stations than any other state. California has six species recorded, one of which is truly terrestrial. At present, it is difficult to determine centers of distribution, but the accumulation of more data should help in ascertaining relations.

By means of a tabular survey of some North American species, one can gain an idea of the range of species relations in the matter of habitat, plant associates, structural diversity, etc. In every subdivision, one can find examples from different regions of the world. North American forms, particularly those of a somewhat extended range, are chosen simply because of more available data.

It may be noticed that all submersed or amphibious forms are related to fresh water. The original account of a salt-water relation for *I. maritima* has since been corrected. The terrestrial forms, *I. melanopoda* and *I. Butleri,* are found in so-called "alkali flats" where the content of magnesium and sodium sulphates is high. These flats are very level, and so become very wet in the spring but are very dry in summer, for the clay or hard pan is covered by too thin a soil layer to hold moisture (E. Hall).

In other regards there is much diversity in habitat relations. Most of the submersed forms are related to lakes or ponds, varying from a few inches to six or more feet in depth. Of the amphibious forms, some are riparian, notably *I. riparia* and *I. saccharata,* but most are found in pools or ponds, where they form a marginal zone, thus becoming exposed in the usual seasonal lowering of the water level. These ponds or lakes may be in meadows, woodland, or as in the case of *I. melanospora,* may be merely low depressions in granite rock, which contain a few inches of soil and which in summer retain no water, leaving the plants to be parched and dried by full exposure to the sun.

Name	Habitat	Associates.	Per str.	Stom.	Velum	Season
		SUBMERSED SPECIES				
I. Braunii Dur.	Ponds, slow streams, lakes; gravel, soft mud, firm sandy soil with silt	*Eriocaulon, Lobelia, Sparganium, Scirpus, Eleocharis*	0	Few	½	June-Sept.
I. Tuckermani A. Br.	Gravelly lake bottoms; gregarious		0	0	Narrow	Aug.-Oct.
I. Bolanderi Engelm.	Lakes, ponds; mud covering gravel; gregarious	*Menyanthes*	0	Few	Narrow	June-Sept.
I. occidentalis Hend.	"Granitic sand"		0	0	Narrow	Aug.-Sept.
		AMPHIBIOUS SPECIES				
I. riparia Engelm.	Gravelly or muddy river banks	*Limosella, Sagittaria, Elatine, Micranthemum*	0	Present	Partial	Aug.-Sept.
I. saccharata Engelm.	Gravelly shores; tidal mud; sand among rocks	*Sagittaria, Eriocaulon, Tillaea, Micranthemum*	0	Present	⅙+	Aug.-Sept.
I. Engelmanni A. Br.	"Ponds and ditches; immersed in mud"	*Polygonum, Lycopus, Carex, Parnassia*	4	Abundant	Narrow	Summer
I. flaccida Shuttlew.	Lakes or swamps; muddy bottoms, "limestone lakelet"	*Nasturtium, Carex*	4	Numerous	Complete	June Aug.
I. cubana Engelm.	"In rivulet"		6	Rare	Narrow	?
I. Tuerckheimii Brause	"Rock fissures in rivulet"		0	At tip	Narrow	Aug.

I. Orcuttii Eaton	Desiccating pools, clay	Grasses, *Calochortus*	0(or 2)	Present	Complete	Feb.-Apr.
I. Pringlei Underw.	Springy places	Grasses	6+6–10 accessory	Numerous	Narrow	Nov.
I. mexicana Underw.	Borders of shallow ponds, to almost terrestrial; sandy plains		4	Numerous	Very narrow	Aug.-Oct.
I. Nuttallii A. Br.	Damp flats	Prairie vegetation	3(or 2)	Numerous	Complete	May-June
I. melanopoda Gay & Dur.	Amphibious to terrestrial; wet prairies, limestone ledges; wet sands	*Nasturtium, Penthorum, Ludvigia, Alisma, Juncus*	4(or 6) (+access-ory)	Numerous	Partial	May-July
I. melanospora Engelm.	"Amphibious. In few inches of soil in naked granite rock."	*Amphianthus pusillus*	0	Present	Complete	May-June

Such plants as this might be considered as grading readily into the more distinctly terrestrial forms. Of these transitional forms, some start growth in very moist habitats, fruit as the season progresses, and die down except for the corm, during the very dry intervals of late July and August. Such plants as these could not have come into consideration when the name "Isoetes, equal at all seasons" was applied. In our country, *I. Orcuttii* of southern California appears "in level pastured meadowland, growing scattered in grassy sod, especially in low places, but never in places where water stands or has stood. The leaves so nearly resemble surrrounding grass in size and color that the plant can scarcely be found except by lifting sod and tearing it apart." In some ways it seems comparable to the Algerian forms, *I. histrix* and *I. Duriaei,* which grow in exposed places, the latter with xerophytic grasses in crevices on granitic mountain slopes.

Plant Associates.—Data in regard to the plants occurring with *Isoetes* are not available in many cases. The table shows what has come to notice in this regard, in some American species. Frequently it would seem that *Isoetes* has few competitors where it succeeds in holding its own. On the the other hand, it may be so thoroughly mixed with grasses, sedges, and other forms of a like habit, that it is easily overlooked.

Physiological and Structural Relations.—In the matter of structural characters, there is an unusual uniformity throughout the group, regardless of environment. All display a corm of two or three lobes, in which reserve material is deposited. In some cases, the corm endures drought for one or more seasons and, with return of moisture, again becomes active. The corm rarely branches, and hence there is no vegetative spread by this method. There is great diversity in number and size of leaves; and though this appears to have no invariable relation to the habitat, smaller forms frequently occur in the terrestrial group. There is a general plan of structure in the leaves which includes four longitudinal air spaces, separated by septa, and surrounded by a peripheral wall of green tissue. There is a tendency for greater development of the air-spaces, with relatively fewer layers (as low as two) of green tissue and narrower septa in the submersed forms. Species in dry situations show less surface development. The leaves are usually narrower with small lacunae, walled by

several layers of compact tissue and separated by as many as five to seven layers in the partitions.

In terrestrial forms, the bases of the leaves often prove persistent. Sometimes they remain as simple brown papery scales, but in their most striking forms they become horny, with extended spines, marginal and central, as in *I. histrix.*

The leaf shows variation in two other directions, in the distribution of groups of mechanical cells in the peripheral region and in presence of stomata. The former may be entirely lacking, as usually occurs in submersed forms, and sometimes in amphibious. With exposure to air, there is development of these groups of supporting cells, often to the number of four, sometimes six, chief aggregations, which are accompanied by smaller ones on occasion. The degree of development of such accessory groups varies greatly. Frequently the upper, more exposed region shows more of these groups of cells.

In the case of stomata, there is no uniformity within the submersed group. *Isoetes echinospora* and a close ally, *I. Braunii* of America, both submersed, show striking dissimilarity in this regard. The former has no stomata, the latter always some. Other species may show even more. In the amphibious and terrestrial forms, it is obvious that there will always be more or less development in the regions exposed to air.

A third leaf feature, the velum, which covers the basal sporangium, has attracted more or less attention. It is included here for that reason, rather than because of any definite correlation with ecological features. The range from very narrow to complete veils seems to be run in each group.

Very little attention has been paid to root systems, which are in all cases fibrous, as a result of dichotomous branching.

Seasonal Relations.—All species of *Isoetes* appear perennial, with a longer or shorter growing season. Submersed forms are reputed to be green during a longer period, as a rule, and usually fruit late, as August to October. A few amphibious forms fruit in the spring, and then die down during the summer, sometimes to become green again in fine fall weather. Engelmann traced through the seasons the activity of *Isoetes Engelmanni,* a vigorous amphibious form, which continues active throughout the summer and fall season, producing spores for a relatively long period. *I. Malinverniana* of the aqueducts of Piedmont, Italy,

is reported as fruiting throughout the summer. Most forms are more restricted, as, for instance, *I. melanopoda* in May and early June, or *I. riparia* in August and September.

After spore production, there is a more or less rapid development of the alternating generation, as shown by Engelmann in his cultures. The sporeling stage then appears in a short interval after spore production, a point demonstrated as early as 1828 by Delile in his careful observations on *Isoetes setacea*. Sporelings produce a small group of leaves which are sterile. Fruiting structures appear only in the second or subsequent seasons.

Geographic Distribution.—It is the experience of collectors that the distribution of *Isoetes* species is remarkably restricted, though there are representatives in most parts of the world.

In North America there is a striking exception to this in *I. Braunii* Dur., a form found both on the east and west coasts, and in much of the territory between these. Maine and Massachusetts are perhaps richest in the number of stations reported, but the form is common in eastern Canada, in the northeastern United States, and is reported less frequently in Ohio, Indiana, Michigan, Wisconsin, and Minnesota. There then appears a considerable gap in the continuity, with the western representatives appearing only as far as Utah, and then westward up the coast.

I. macrospora Dur. and *I. Engelmanni* A. Br. possibly represent the forms next most widely distributed. The former is northern, like *I. Braunii*, and is found in eastern Canada, and the northern United States as far west as Minnesota. *I. Engelmanni* is of slightly more southerly occurrence, and is found from New England, west to the Mississippi Valley, with Engelmann's own station at St. Louis as the farthest west.

More restricted in character are the following species of the eastern border: *I. Tuckermani, I. riparia, I. saccharata, I. Eatoni,* and *I. foveolata.* Farther south, in Georgia and Florida, occur *I. flaccida* and its variety *alata,* while *I. melanospora* is endemic in one station, Georgia, and *I. lithophila* in Texas.

In the central states, besides *I. Engelmanni,* the form *I. melanopoda* Gay & Dur. proves of rather extended range in Illinois, Missouri, Nebraska, Iowa, Oklahoma, and Texas. Its companion form, *I. Butleri,* occurs in the western part of this range in even drier localities.

The west coast of the continent boasts of eight distinctive species and three varieties. Of these, four species are especially northern in character, occurring in Washington or farther north, i. e., *I. Piperi, I. Flettii, I. occidentalis, I. truncata.* Four are either more extended to the south, as *I. Nuttallii, I. Howellii,* and *I. Bolanderi,* or restricted to southern California, as *I. Orcuttii.*

This last species even extends into Lower California, and therefore, with *I. mexicana* and *I. Pringlei,* represents the genus in Mexico.

The West Indies yield two endemic forms, *I. cubana* (Cuba) and *I. Tuerckheimii* (Haiti).

Of the South American forms, three are reported for Brazil, *I. amazonica, I. Gardneriana,* and *I. Martii.* Three others, less known in collections, occur in more remote stations, *I. Lechleri* (Argentine), *I. triquetra* (Peru), and *I. Savatieri* (Patagonia).

The situation in Europe is somewhat parallel to that in North America in that two species have a rather wide range in the northern territory. *I. lacustris* and *I. echinospora* are found in the British Isles and on the continent in the northern countries. Aside from these, there are eight other forms on the continent more local in distribution, and three in Mediterranean islands. In France, we find *I. setacea, I. Boryana, I. tenuissima, I. histrix,* and *I. Brochoni;* in Italy, the giant *I. Malinverniana;* in Greece, *I. Heldreichii,* and in Spain, *I. baetica* (probably not a valid species). In the Mediterranean islands, Corsica, Sardinia, or Sicily, are reported *I. dubia, I. velata,* and *I. tegulensis. I. azorica* is reported only from the Azores.

To date, the genus appears much more sparse in Asia, with *I. olympica* for Asia Minor, *I coromandelina* for India, and *I. echinospora* var. *asiatica* and *I. japonica* for Japan.

In Africa, Algeria shows especially marked abundance of forms in that *I. histrix, I. Duriaei, I. adspersa, I. velata* and its variety, *Perralderiana,* all occur here. Farther south, *I. nigritiana* has been reported for the River Niger, and *I. Schweinfurthii* in the Anglo-Egyptian Sudan. In southern Africa, Angola gives us *I. Welwitschii* and *I. aequinoctialis. I. Wormaldii* and the little-known *I. natalensis,* which may prove a valid species, are forms from the Cape.

Oceanica proves very rich in forms, with three each in Australia (*I. Drummondii, I. Muelleri,* and *I. tripus*) and Tasmania (*I. Gunnii, I. elatior,* and *I. humilior*), and two allies in New Zealand (*I. alpina* and *I. Kirkii*).

Floristic Relations.—Some of the Mediterranean forms, as *I. velata, adspersa, Boryana, tegulensis,* and *tenuissima* and *I. velata Perralderiana,* show a very close relation as though originating from a single stock, which may be referred to as the Eur-African stock. No other morphological group as large as this is found in so limited a geographical region. The two New Zealand species, *I. alpina* and *I. Kirkii,* show evident relations to each other. But associated morphologically with these eight forms are many others in widely distant stations, as *I. cubana* of Cuba, *I. Schweinfurthii* of Central Africa, *I. Orcuttii* of southern California. Obviously it is impossible to determine any basic forms here.

In what might be termed the *Echinatae* group, one finds many reports of *I. echinospora* itself in Europe, the closely related *I. Braunii* in our northern territory (the two probably bridge the Atlantic Ocean in the Arctic islands), and a variety in Japan which presents a difficulty in the attempt to ascertain to which it is the more closely related. There are representatives of this group also along the west coast of North America, up to Alaska. Obviously there is a more or less continuous northern band about a large part of the known territory. Discontinuity may be due to lack of present forms or to lack of knowledge of such forms.

The other morphological groups show rather a similar situation to the first-mentioned group, with representatives scattered in north, south, east and west hemispheres.

It may be noted that the distribution of diverse species, of a remarkably conservative genus, is striking in the number of insular and coastal region forms which appear.

Material Examined

The present monograph was suggested to the writer by Dr. J. M. Greenman, under whose guidance the work has come to completion at the Herbarium of the Missouri Botanical Garden. To him especial thanks are due for encouragement, suggestion, and advice in the progress of the problem. The writer is indebted

to the Garden for the use of the excellent collections of *Isoetes*, comprising the collections of two students of the group, Dr. George Engelmann and A. A. Eaton, for the use of the original notes of these workers, and for grants which made it possible to pursue this work. It is also a pleasure to acknowledge the kindness of Dr. Wm. R. Maxon, who placed the material of the United States National Herbarium at the writer's disposal; of Dr. Aven Nelson and Dr. C. O. Rosendahl, who loaned the material from the herbaria of the University of Wyoming and the University of Minnesota, respectively; of Prof. L. R. Abrams, who supplied some west-coast forms from the Dudley Herbarium of Leland Stanford University; of Dr. S. Schönland of South Africa, Dr. D. A. Herbert and Prof. T. G. S. Osborn of Australia, Mr. L. Rodway of Tasmania, and Dr. W. S. Dudgeon of India, for material of exotic species.

The writer has also enjoyed the privilege of examining the sheets of *Isoetes* in the Gray Herbarium, in the Herbarium of the New York Botanical Garden, and in the Field Museum of Chicago. To those in charge who have facilitated this work, she desires to express her appreciation of the privileges enjoyed and the courtesies extended.

In the matter of photographic illustrations, the writer is especially grateful for the suggestions and aid given by Dr. J. W. G. Land of the University of Chicago.

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Relationships in Genus

The species of *Isoetes* might be considered from the point of view of the sculpture of the megaspore wall as representing a long series from those with simple distinct prominences to those with extended ridges or crests, finally becoming reticulate. In this long series many forms stand out distinctly. But with abundance of material there is often much evidence of intergrading between adjacent forms and even of variation within the same species. As an example of the latter, one might cite the case of *I. Bolanderi* of the west coast of America, a form ordinarily adorned with low tubercles, which on occasion fail to

appear, leaving a smooth surface. As illustration of intergrading between closely related forms, the *I. velata* complex of the Mediterranean region serves well. Here one must use all the available distinctions to hold the forms apart; yet, were these not used, the result would be simply a complex, incapable of treatment as a unit. Examples of pairs of species in which the same difficulty arises are *I. riparia* and *I. saccharata, I. macrospora* and *I. Tuckermani, I. echinospora* and *I. Braunii*. In all these cases, absolute separation on spore characters alone would be a difficult task; other features, even geographical range, may prove invaluable as supplementary points.

In all instances, it has been the aim of the writer to so treat the forms as to avoid points of an insignificant nature and to emphasize what seemed more important features. Only fairly definite varieties have been maintained. In some cases, it has been necessary to reduce long-recognized varieties and forms, in others those of more recent standing. Possibly this has occurred more frequently than usual in a work of this sort. The most obvious explanation for this is related to the relatively rare occurrence of the genus in the experience of most workers. The result of this is the seeming distinctiveness of any single collection made. One other possible result of inexperience is description based on immature material. Many collections of under-ripe plants are made without realization of the absolute necessity of mature characteristics for positive determination.

It is furthermore not always easy to determine from collections, sometimes scant in amount and accompanied by few or no habitat notes, to exactly what extent ecological factors have resulted in variations. The writer is inclined to believe that such variations have at times been the basis for described varieties and has attempted in this work to avoid as far as possible classification of varieties and forms resulting from such factors as the relative dryness of the season.

Species not Examined

Isoetes as a genus is distributed widely over the earth in very local fashion, frequently in remote and inaccessible stations. In such a group, it is not surprising that some forms have been collected only once, nor is it unexpected that representation

should be lacking in America of some of these less well-known forms. In spite of efforts extending over a considerable interval of time, it has not been possible to obtain adequate material of the following described species: *I. Welwitschii, aequinoctialis, Heldreichii, nigritiana, dubia, olympica, Gardneriana, elatior, Muelleri, humilior, triquetra, echinospora* var. *asiatica, tripus, Savatieri, neoguiniense, baetica, natalensis.*

Wherever possible these species have been placed in the keys according to the characters found in the literature. The species descriptions are based either entirely on the original description, directly quoted or translated, or on that plus supplementary material in later accounts. It has been a matter of concern to choose what seemed authentic. Unfortunately, the monograph of Motelay and Vendryès, which should be of great aid here, has so many typographical errors that one lacks confidence in its reliability.

Keys

In the preparation of keys, the attempt has been made to use as evident characters as possible, such as plant size, character of leaf, and similar features. Unfortunately such points are dependent to some extent on external conditions which may prove variable. An effort has been made to take such variations into account; obviously, some errors in judgment, especially because of the use of dried material apart from its habitat, will occur, which in some degree render the key inaccurate. Measurements might better, therefore, be interpreted as suggestive of the probable range rather than as absolute limits.

Furthermore, it has been necessary to utilize minute characters, some of which are not readily determined, particularly in dried material. Previous investigators, as Braun and Engelmann, have stressed this point adequately. The latter further emphasized the skill that even the amateur can develop with the opportunity to study fresh material of several forms, so that standards of comparison may be developed. A little more care is required with the use of dried plants, which involves soaking and more careful methods in dissecting and sectioning.

Again, with these minute characters, such as ligule and degree of velum development, it is very difficult to more than approximate an accurate description. In regard to such a feature as

spore sculpture words prove at times a difficult mode of conveying an exact picture of the various markings. Recourse has therefore been had to photographs, which will serve to counteract the shortcomings of verbal description.

In the case of microspore markings, the point should be borne in mind that in such tiny structures the degree of magnification plays an unusually large role. This is true in much smaller degree of the megaspores. The description for microspores has been based on what may be seen with a magnification approximating 100 diameters, that for megaspores, about 50 to 60 diameters.

Isoetaceae Reichb.

Isoetaceae Reichb. H. G. L. Consp. Reg. Veg. 43. 1828; Dumortier, Anal. Fam., Pl. 68. 1829; Bartling, Ord. Nat. Pl. 13–14. 1830; Endl. Gen. Pl. 68–69. 1838–40; Schnizlein, Icon. Fam. Nat. Reg. Veg. 35 . 1843-46; Ledeb. Fl. Rossica 4: 495. 1853; Underwood, Our Native Ferns & Fern Allies, 121. 1882; Boissier, Fl. Orient. 5: 746. 1882; Kuhn in Martius, Fl. Brasil. 1^2: 646. 1884; Luerrsen, Farnpfl. Deutschl. 845. 1889; Kuntze, Rev. Gen. Pl. 2: 828. 1891-93; Ascherson & Graebner, Syn. Mitteleur. Fl. 1: 163. 1896-98; Sadebeck in Engl. & Prantl, Nat. Pflanzenfam. 1^4: 756. 1901-02; Small, Fl. Southeastern U. S., ed. 1, 24. 1903, and ed. 2, 30. 1913; Clute, Fern Allies, 207. 1905; Piper, Contr. U. S. Nat. Herb. 11: 88. 1906; Eaton in Gray, Man. Bot., ed. 7, 58. 1908; Coulter & Nelson, Bot. Rocky Mts. 24. 1909; Underwood in Britton & Brown, Ill. Fl., ed. 1, 45. 1896; Maxon in Britton & Brown, Ill. Fl., ed. 2, 50. 1913; Rydb. Fl. Rocky Mts. 1053. 1917.

Aquatic to terrestrial herbs with a short unbranched, lobed, subterranean axis producing many dichotomous roots and grass-like leaves, the enlarged bases of which contain solitary, sessile, adaxial sporangia, more or less covered by a thin extension of tissue or velum. Sporangia of two sorts, producing large tetrahedral megaspores and minute powdery microspores, respectively.

ISOETES L.

Isoetes L. Sp. Pl. 1100. 1753; Gen. Pl. 486, gen. no. 1048. 1754; Amoen. Acad. 3:25, gen. no. 1109. 1756; Syst. Nat., ed. 10, 1330, gen. no. 1048. 1759; ed. 12, 697, gen. no. 1184. 1767; ed.

13, 1284, 1322, gen. no. 1184. 1791; Syst. Veg., ed. 13, 792, gen. no. 1184. 1774; Sadebeck in Engl. & Prantl, Nat. Pflanzenfam. 1^4: 756. 1901-02.

Marsilea L. Fl. Suec. 996. 1745.

Calamaria Dillen. Hist. Musc. 541. *pl. 80. fig. 2.* 1741; Kuntze, Rev. Gen. Pl. 2: 828. 1891-93; Post & Kuntze, Lexicon, 88. 1904.

Subularia Ray, Syn. Meth. Stirp. Brit. 283. 1696.

Cephaloceratodon Genn. Comment. Critt. Ital. [1] no. 2: 111. 1861.

Isoetella Genn. Comment. Critt. Ital. [1] no. 2: 114. 1861.

Perennials, submerged, amphibious, or terrestrial, with a 2-or 3-lobed, short fleshy axis or corm giving rise to numerous branched roots and to a rosette of elongated, somewhat triangular or quadrangular leaves. Leaves with 4 transversely septate, longitudinal air-channels, with central fibro-vascular bundle; peripheral groups of supporting cells present or absent, stomata present or absent. Ligule a small, delicate, triangular extension of tissue on inner face of leaf above the sporangium. Sporangium solitary, sessile, on adaxial side of leaf, contained within a basal cavity, and more or less covered by a membranous tissue, the velum, on the inner leaf face. Sporangia of two types, microsporangia and megasporangia, bearing respectively microspores and megaspores, which on germination develop gametophytes, the former with a single antheridium, the latter with archegonia. Megaspores hemispherical at base, with equatorial ridge, and three other crests joined at apex, with variously sculptured walls. Microspores minute, powdery, usually oval.

Type species *I. lacustris* L. Sp. Pl. 1100. 1753.

Key to Sections

A. Surface of megaspores chiefly tuberculate or spiny.
- a. Megaspores tuberculate ----------§1. **Tuberculatae**
- b. Megaspores spiny ----------§2. **Echinatae**

B. Surface of megaspores irregularly crested or reticulate.
- a. Megaspores irregularly crested ----------§3. **Cristatae**
- b. Megaspores reticulate, at least on basal face ----------§4. **Reticulatae**

Sect. 1. Tuberculatae

§ 1. Tuberculatae. Forms with 2 or 3-lobed corms; megaspores rarely smooth, usually marked with few or many large warts or many small tubercles, chiefly simple.

Key to Species

A. Forms with 3-lobed corms; megaspores marked with few to many large rounded tubercles; microspores rough; leaves mostly slender, usually with peripheral strands and stomata. Chiefly forms of the eastern hemisphere.

a. Velum none or little developed.

α. Terrestrial forms.

I. Leaves few, velum none ---------- *1. I. Welwitschii*

II. Leaves many, velum covering ½–⅔ of sporangium. *2. I. aequinoctialis*

β. Forms not terrestrial in habit.

I. Megaspores more than 400μ in diameter.

1. Leaves few in number, less than 20.

*Stomata present.

†Peripheral strands well-developed ---------- *3. I. Schweinfurthii*

††Peripheral strands variable (none–6) ---------- *3.5. I. ovata*

**Stomata absent ---------- *4. I. Heldreichii*

2. Leaves more than 20 in number.

*Megaspores 480–540 μ in diameter, with large tubercles ---------- *5. I. coromandelina*

**Megaspores 565–680 μ in diameter, with numerous smaller tubercles ---------- *6. I. setacea*

***Megaspores 660–800 μ in diameter, with elongated coarse processes ---------- *7. I. Malinverniana*

II. Megaspores chiefly less than 400 μ in diameter.

1. Leaves not filiform, more than 25 cm. long ---------- *8. I. cubana*

2. Leaves filiform, less than 25 cm. long.

*Megaspores gray ---------- *9. I. nigritiana*

**Megaspores white ---------- *10. I. adspersa*

b. Velum complete or nearly so.

α Megaspores with few coarse warts.

I. Megaspores becoming dark when wet.

1. Coarse plants, more than 15 leaves, more than 12 cm. in length ---------- *11. I. Boryana*

2. Finer plants, less than 15 leaves, less than 15 cm. in length ---------- *12. I. tenuissima*

II. Megaspores creamy when wet.

1. Leaves chiefly less than 24 cm. in length.

*Leaves slender and short.

†Leaves more than 10 cm. long.

o Megaspores more than 480 μ in diameter ---------- *13. I. dubia*

oo Megaspores less than 480 μ in diameter -- *15a. I. velata* var. *Perralderiana*

††Leaves less than 5 cm. long ---------- *14. I. olympica*

**Leaves coarser, chiefly less than 24 cm. in length, rarely longer ---------- *15. I. velata*

2. Leaves longer, chiefly more than 22 cm. in length -- *16. I. tegulensis*

β. Megaspores with more numerous regular tubercles.

I. Leaves more than 15 cm. long, more than 10 in number -- *17. I. alpina*

II. Leaves less than 15 cm. long, less than 10 in number -- *18. I. Kirkii*

B. Forms with 2- or 3-lobed corms; megaspores rarely smooth, usually marked with numerous small tubercles, sometimes confluent; microspores smooth or rough; peripheral strands and stomata variable among species.

a. Corms 3-lobed.

α. Velum none or little developed.

I. Leaves short, less than 11 cm. in length.

1. Stomata absent ---------- *19. I. Gunnii*

2. Stomata present.

*Megaspores less than 470 μ in diameter ---------- *20. I. Drummondii*

**Megaspores more than 420 μ in diameter ---------- *21. I. amazonica*

II. Leaves long, more than 20 cm. in length.
1. Peripheral strands and stomata present ---------*22. I. Gardneriana*
2. Peripheral strands and stomata absent ----------*23. I. elatior*

β. Velum complete.
I. Amphibious; leaves 7 cm. long ----------*24. I. Muelleri*
II. Terrestrial.
1. Leaf-bases persistent, conspicuous, usually spiny ----*25. I. histrix*
2. Leaf-bases sometimes persistent, not conspicuous.
*Leaves more than 13 in number, longer than 8 cm. --*26. I. Nuttallii*
**Leaves less than 15 in number, less than 8 cm. ------*27. I. Orcuttii*

b. Corms 2-lobed.

α. Velum complete.
I. Megaspores dark when wet, small-tuberculate.
1. Megaspores large, more than 600 μ in diameter ----*28. I. humilior*
2. Megaspores small, less than 480 μ in diameter.
*Leaves less than 7 cm. long; megaspores more than 360 μ ----------*29. I. melanospora*
**Leaves more than 7 cm. long; megaspores less than 360 μ ----------*30. I. lithophila*
II. Megaspores white or creamy.
1. Megaspores marked with large warts.
*Warts always simple ----------*31. I. flaccida*
**Warts confluent into bold ridges on the basal face --*31a. I. flaccida* var. *alata.*
2. Megaspores marked with very low tubercles.
*Stomata present ----------*32. I. Lechleri*
**Stomata lacking ----------*33. I. triquetra*

β. Velum narrow, usually covering not more than one-third of sporangium.
I. Megaspores with tubercles frequently confluent into wrinkles.
1. Amphibious; stomata and peripheral strands usually evident.
*Megaspores more than 420 μ in diameter ----------*34. I. Howellii*
**Megaspores less than 420 μ in diameter ----------*34a. I. Howellii* var. *minima*
2. Submerged; stomata few, peripheral strands lacking.
*Leaves more than 6 cm. long, slender ----------*35. I. Bolanderi*
**Leaves less than 6 cm. long, stout ----------*35a. I. Bolanderi* var. *pygmaea*
II. Megaspores with chiefly simple tubercles.
1. Peripheral strands lacking ----------*36. I. Tuerckheimii*
2. Peripheral strands present.
*Megaspores less than 480 μ in diameter.
†Surface of spore smooth or with large simple tubercles. ----------*37. I. mexicana*
††Surface of spore with small tubercles, sometimes confluent. ----------*38. I. melanopoda*
**Megaspores more than 480 μ in diameter ----------*39. I. Butleri*

1. Isoetes Welwitschii A. Br. in Kuhn, Fil. Afr. 196. 1868; A. Br. Sitzb. Naturf. Fr. Berlin, 7. 1867; Motelay & Vendryès, Actes Soc. Linn. Bord. **36**: 388. 1883.

Calamaria Welwitschii Kuntze, Rev. Gen. Pl. 2: 828. 1891-93.

Corm 3-lobed; leaves 6–15, rigid, straight or slightly curved, firm, very fine, pale green surrounded at base by some dark scales; stomata numerous; peripheral strands 4 primary, accessories none in front, 4 on each side in back; velum very narrow,

almost none; ligule elongated, little shorter than the sporangium; megaspores 300–360 μ and 480–540 μ, dimorphous in same sporangium, ashy when dry, with white markings; warts prominently numerous on the basal face, larger and smaller intermixed, on apical faces all small, very numerous; microspores 30 μ long, 20 μ wide, somewhat acute, with scattered minute inconspicuous tubercles.

Distribution: Huilla, District of Angola, Africa.

No authentic specimens seen.

2. I. aequinoctialis Welw. in Kuhn, Fil. Afr. 195. 1868; A. Br. Sitzb. Naturf. Fr. Berlin, 7. 1867; Motel. & Vendr. Actes Soc. Linn. Bord. **36**: 365. 1883.

Calamaria aequinoctialis Kuntze, Rev. Gen. Pl. **2**: 828. 1891-93.

Corm 3-lobed; leaves numerous, 30–40 cm. long, rigid, firm; stomata numerous; peripheral strands 4 primary and 18–24 weaker accessory; ligule elongate triangular, shorter than sporangium; velum incomplete, covering ½–¾ of the sporangium; sporangium globose; megaspores dimorphous, 380–480 μ and 550-620 μ in diameter, cinereous, ornamented by white commissural ridges and warts; warts coarse, hemispherical, distant, sometimes doubly confluent, 5–6 on apical faces, solitary or few confluent in smaller megaspores; microspores 30–40 μ long, 25–35 μ thick, strongly obtuse, densely spiny. Description compiled.

Distribution: Angola, in wet prairies of Pungo Andago, 8–1200 m. altitude.

3. I. Schweinfurthii A. Br. in Baker, Jour. Bot. **18**: 108. 1880; Motel. & Vendr. Actes Soc. Linn. Bord. **36**: 380. 1883.

Calamaria Schweinfurthii Kuntze, Rev. Gen. Pl. **2**: 828. 1891-93.

Corm 3-lobed; leaves 9–25, 25–32 cm. long, firm, gradually tapering to an acute apex, with membranous margin developed 1–3 cm. above level of sporangium; stomata common; peripheral strands 4 (or 6) cardinal, strongly developed, plus 6–8 accessory groups; ligule short, broad triangular; sporangium ovoid to oblong, 4–6 mm. long, with velum none or exceedingly nar-

row; megaspores white, creamy when wet, 400–500 μ in diameter, with few large warts on apical faces, more numerous on basal; microspores 27–32 μ in length, almost smooth.

Distribution: Central Africa, Kingdom Djur.

Specimen examined:

Africa: Anglo-Egyptian Sudan, Jur Ghattas, 7° N., under water, June-July, 1869, *Schweinfurth* (Mo. Bot. Gard. Herb.).

The habit is much like that of *I. Boryana* Dur. except for longer leaves which are commonly coarser than those of the forms *I. velata* and its allies, *tenuissima, tegulensis,* etc., as well as *I. setacea* Bosc. It differs further from these forms in that the velum is lacking, in contrast to being practically completely developed. The megaspores do not turn dark in moisture, as do those of *I. Boryana.*

The species can be delimited from *I. adspersa* A. Br., which is similar in lacking a velum, in that it has far coarser, as well as longer, leaves, that the megaspores are larger (over 400 μ rather than with that as a maximum), and that the microspores are smooth rather than long spinulose.

Contrary to Baker's and Motelay and Vendryès' description, I find the megaspores large tuberculate, with such markings that they might easily be confused with *I. Boryana* Dur., *I. tegulensis* Genn., *I. tenuissima* Bor., etc. I find no evidence of honeycombing in my material, part of which is from the herbarium of Motelay himself.

3.5 I. ovata Pfeiffer, n. sp.[1]

Corm 3-lobed; leaves 7–15, 6–24 cm. long, slender, tapering to apex, with basal membranaceous margins but briefly extended; stomata present; peripheral strands lacking or six in number; ligule deltoid, with broad base; sporangium small, ovoid, 2.5–4 mm. long, lacking a velum; megaspores cream-colored, 520–830 μ in diameter, with high well-rounded large tubercles, seldom becoming somewhat verniform; commissural ridges decidedly

[1] **I. ovata** sp. nov. Cormus trilobatus. Folia numero 7–15, longitudine 6–24 cm., angusta, versus apicem attenuata, basi membranacea breviter dilatata, stomatibus instructa et fibrosis peripheriçis vel nullis vel numero sex instructa. Lingula triangularis, basi lata. Sporangium ovatum, parvulum, longitudine 2.5–4 mm., sine velo. Macrosporae gilvae, diam. 520–830 μ, tuberculis crassis prominulis, raro aliquantulum verruculosis ornatae, costis commissuris teretibus, aliquando decussatim rugosis. Microsporae longitudine 31–36 μ, leviter reticulatae.

rounded, and occasionally cross-wrinkled; microspores fawn-colored, 31–36 μ, lightly reticulate, with ridges spine-like in silhouette.

Distribution: British Guiana.

Specimens examined:

British Guiana: pools by shore of Mazaruni River, Demerara, December, 1890, *Jenman* (N. Y. Bot. Gard. Herb.), TYPE; Baracarra, Mazaruni River, Demerara, December, 1890, *Jenman* (N. Y. Bot. Gard. Herb.).

4. I. Heldreichii Wettst. Verh. K. K. Zool.-Bot. Ges. Wien **36**: 239–240. *pl. 8.* 1886, whence the following description:

Corm 3-lobed, 3–6 mm. long, 3–7 mm. broad; leaves 3–8, fine, flexuous, green, smooth, 10–25 cm. long; no peripheral strands or rarely one dorsal; no stomata; ligule obovate-acute, very finely and irregularly cut; sporangia 4–6 mm. long, without velum; megaspores 14–36 in number, creamy white, globose, inconspicuously trigonous, about 660 μ in diameter, warty [plate shows 12 or so warts on one of upper faces]; microspores powdery, elliptical, with narrow winged margin, and marked with short spines.

Distribution: Greece, plains of Thessaly.

Specimen examined:

Greece: amphibious in wet places, schistose substratum, in lower region of Pindus Mountains, alt. 3500′, 5 July, 1885, *Heldreich 899* (Gray Herb.).

5. I. coromandelina L. fil. Suppl. Pl. 447. 1781; A. Br. Verh. Bot. Ver. Brandenb. 4: 327. 1862; Motel. & Vendr. Actes Soc. Linn. Bord. **36**: 380. *pl. 15. fig. 7.* 1883.

I. brachyglossa A. Br. Verh. Bot. Ver. Brandenb. 4: 327. 1862.

I. capsularis Griffith, not Roxb., in Posth. Papers, Cryptog. Pl. 572–575. *pl. 116–118.* 1849.

Calamaria coromandelina Kuntze, Rev. Gen. Pl. **2**: 828. 1891-93.

Corm 3-lobed; leaves 20–60, large, with very wide membranous wings at base, extending above sporangium level; stomata numerous in upper region, lacking in basal portion of leaves; peripheral strands present, 4 very strongly developed with sev-

eral weaker accessory; ligule conspicuous, very wide and short, often appearing truncate in older leaves, but pointed in young; sporangium large, maximum about 12 mm. in length and 9 mm. in width; velum none; megaspores white when dry, gray when moist, 480–540 μ in diameter, somewhat flattened, marked with numerous large tubercles, closely arranged and occasionally extended into very short rounded ridges; microspores red-brown or paler at maturity, 26–33 μ, chiefly 30 μ, smooth.

Distribution: India.

Specimens examined:

India: Madras, 1919, *Fyson* (Mo. Bot. Gard. Herb.); Peninsula of India, without date, *Royle* (?) (Gray Herb.); "Peninsula Ind. orientalis," *Herb. Wight. Cryptogamia 4* (N. Y. Bot. Gard. Herb.); near Seven Pagodas, Madras, February, 1922, *Kashyap* (Mo. Bot. Gard. Herb.).

Dr. W. S. Dudgeon, through whose courtesy material from India was obtained, gives the assurance of local botanists that there is but one species in India. The chief difference between the descriptions of *I. coromandelina* and *I. brachyglossa* seems to be one of leaf length, which would not be a character of specific rank.

The specimens examined were very large in the sporangium region, reminding one of the giant *I. Malinverniana* of Europe. All mature sporangia proved to bear megaspores. No published record for microspores appears available in the literature concerning either *I. coromandelina* or *I. brachyglossa.* The measurements made as reported above were made from spores scattered among the sporophylls, sometimes in small groups but in all cases distinctly recognizable as *Isoetes* microspores. Some are unusually brilliant with orange-red coloring, possibly due to chemicals.

6. I. setacea Bosc, "Dict. d' Hist. Nat." in Delile, Mem. Mus. Paris **14**: 100–119. *pl. 6–7.* 1827; (Lamarck, Encycl. Meth. **3**: 314. 1789.) (?); A. Br. Verh. Bot. Ver. Brandenb. **4**: 30. 1862; Baker, Fern Allies, 129. 1880, and Jour. Bot. **18**: 106. 1882; Milde, Fil. Eur. 286. 1867; Motel. & Vendr. Actes Soc. Linn. Bord. **36**: 376. *pl. 11. fig. 1–2.* 1883.

Calamaria setacea Kuntze, Rev. Gen. Pl. **2**: 828. 1891-93.

Corm 3-lobed; leaves 10–40 (rarely 60), 12–40 cm. long, light green, firm but not stiff, tapering to apex, with wide membranaceous margin at base gradually narrowed to disappearance 1–2 cm. above sporangium level; stomata present in upper parts of leaves; peripheral strands variable, but chiefly 6 plus accessory strands; ligule longer than wide; sporangia 4–6 mm. long, lightly marked with sclerenchyma cells; velum none; megaspores white, 564–680 μ (rarely 800) in diameter, densely crowded on all faces with small warts or tubercles; commissural ridges prominent and wide; microspores 27–37 μ long, usually with slightly crenulate margins and with low crest.

Distribution: Montpellier, Herault, France.

Specimens examined:

France: Grammont, near Montpellier, December, 1820, *Ballard* (Gray Herb.); Montpellier, *ex Herb. Engelmann* (Mo. Bot. Gard. Herb.); mare de Grammont pres Montpellier, *Delile* (N. Y. Bot. Gard. Herb.); lac de Grammont, August, 1837, *de Gerard* (Mo. Bot. Gard. Herb.); Montpellier, Grammont, 21 March, 1840, *Bubani* (U. S. Nat. Herb.); Montpellier, 1842, *Wanderley* (Mo. Bot. Gard. Herb.); Montpellier, Grammont, 30 June, 1842, *without collector* (Mo. Bot. Gard. Herb.); pools of plateau of Roquehaute, 7 June, 1863, *Durieu 21* (N. Y. Bot. Gard. Herb.); pond near Montpellier, 8 June, 1857, *Cosson* (Gray Herb., Mo. Bot. Gard. Herb., and N. Y. Bot. Gard. Herb.); near Beziers (Herault), and Juire, 1879, *Gautier* (N. Y. Bot. Gard. Herb.); Montpellier, 1866, *Cosson* (Mo. Bot. Gard. Herb.); marsh, Roquehaute near Beziers (Herault), 3 June, 1862, *Cosson* (Mo. Bot. Gard. Herb., N. Y. Bot. Gard. Herb., and Gray Herb.); pool, Roquehaute, June, 1862, *Durieu* (Mo. Bot. Gard. Herb.); "in almost all the ponds of the volcanic plateau of Roquehaute, Herault," 17 May, 1864, *Motelay* (Mo. Bot. Gard. Herb.); ponds of Roquehaute, 11 May, 1864, *Cheveneau* (U. S. Nat. Herb.); pond of Roquehaute near Beziers, June, 1869, *Cheveneau* (Gray Herb.); near Montpellier, Grammont, 6 June, 1884, *without collector* (U. S. Nat. Herb.); pond at Grammont near Montpellier, November, 1876, *Duval-Jouve* (Gray Herb.); Grammont near Montpellier, 10 May, 1888, *Herb. Fac. Scient. Monsp.* (U. S. Nat. Herb.); Portiragnes (Herault), ponds in plateau of Roquehaute, 1 April, 1888,

Neyraut (Mo. Bot. Gard. Herb.); Montpellier, in pond of the woods of Grammont, 16 June, 1889, *Herb. Copineau* (U. S. Nat. Herb.); pond near Montpellier, 1892, *de la Perraudiere* (Mo. Bot. Gard. Herb.); ponds of Roquehaute, Herault, 15 May, 1895, *Mandon* (Mo. Bot. Gard. Herb.); Portiragnes, Roquehaute, 2 May, 1896, *Sennen* (Mo. Bot. Gard. Herb.); Portiragnes, Herault, ponds in plateau of Roquehaute, 6 November, 1897, *Neyraut* (Mo. Bot. Gard. Herb.); plateau of Roquehaute, May, 1898, *Herbarium Normale, I. Dorfler, (Neyraut) 3698,* (U. S. Nat. Herb.); Montpellier, Herault, 20 February, 1898, *Mandon* (Univ. Minn. Herb.); Portiragnes, 8 May, 1898, *Neyraut* (Mo. Bot. Gard. Herb. and U. S. Nat. Herb.); Montpellier, in the ponds of Grammont, 3 July, 1907, *Societe Cenomane d'Exsiccata* [*Jean de Vichet*] *482* (Mo. Bot. Gard. Herb.); Lac de Grand Lieu, 27 September, 1880, *without collector* (Mo. Bot. Gard. Herb.); without locality or date, *DeCandolle* (N. Y. Bot. Gard. Herb.).

Historically one of the oldest species of *Isoetes, I. setacea* Bosc was the subject of a detailed and interesting account by Delile, who credited Bosc with the name for this species of central France, as published in Dictionnaire d'Histoire Naturelle. The lack of velum associated with the numerous small tubercles of the megaspore and the rather firm but flexuous, fine leaves, make distinctive points of difference between this form and the *I. velata* series (complete velum), *I. adspersa* A. Br. (large warts on smaller spores), and *I. Malinverniana* Genn. (larger tubercles on larger spores in much coarser plant).

The distribution of peripheral strands is the most variable possible; most frequently there are six at the cardinal points, with numerous other groups irregularly arranged beneath a much thickened epidermal layer. Sometimes these groups are so numerous as to make an almost continuous band. On the other hand, the cardinal bundles may be very weak; or only four of them may be developed; or, most extreme situation of all, there may be no development of these thickened cells. The different possible arrangements may be found in the same plant, where the base of the leaf shows no peripheral strands and the apex a fairly strong development. Doubtless there is a response to external factors.

7. I. Malinverniana Cesat. & De Not. Ind. Sem. Hort. Reg. Bot. Genuensis, 1858; Ann. Sci. Nat. Bot. 4: 381. 1859; Linnaea **30**: 741. 1859-60; Baker, Jour. Bot. **18**: 106. 1880; Motel. & Vendr. Actes Soc. Linn. Bord. **36**: 342. 1883.

Calamaria Malinverniana Kuntze, Rev. Gen. Pl. **2**: 828. 1891-93.

Corm 3-lobed; leaves 90–100, 30–80 cm. long, rich green, prismatic, subulate, with narrow membranous margin little extended (0.5–1.0 cm.) above level of sporangium; stomata few; peripheral strands 6; ligule lanceolate; sporangia oblong, 2–2.5 cm. long; velum none; megaspores white when dry, ashy when wet, 660–800 μ in diameter, with long coarse processes (sometimes 80 μ in length), rounded at tip, extending on all faces between narrow commissural ridges wavy in outline, frequently with large compound knob occurring on upper face in angle formed by ridges; microspores 33–38 μ (rarely 29 μ) in length, spiny.

Distribution: Piedmont, in Italy.

Specimens examined:

Italy: in slow-flowing water in aqueducts, "Greggio and Oldenico," Piedmont, fruiting all summer, through the fall, even into winter, 1865, *Cesati* (Mo. Bot. Gard. Herb. and N. Y. Bot. Gard. Herb.); near Oldenico, Piedmont, 3 May, 1863, *Ascherson* (Mo. Bot. Gard. Herb., N. Y. Bot. Gard. Herb., and Gray Herb.); ditches about Vercelli, "note de Durieu dans son herbier: recu vivant de M. Malinverni, le 25 Octobre, 1867," *Malinverni* (Mo. Bot. Gard. Herb.); Piedmont, prov. Novara, in fountains and aqueducts, submersed, floating, throughout year, 1910, (*Gola*) *Fiori & Béguinot 1606* (Gray Herb.); near Oldenico, Piedmont, 1859, *Malinverni*, (N. Y. Bot. Gard. Herb.).

This species is the giant form of Europe in leaf number and length. The size of its megaspores is equalled only by that of *I. Duriaei* Bory, which, however, in other features is a much smaller plant. The coarse, long processes, visible to the naked eye, and the peculiar large grains, compounded as it were from a number of warty prominences, are definitely characteristic of this species.

8. I. cubana Engelm. Trans. St. Louis Acad. Sci. 4: 389. 1882; Sauvalle, Fl. Cub. 203. 1873, name only; Baker, Jour. Bot.

18: 110. 1880, and Fern Allies, 133. 1887; Motel. & Vendr. Actes Soc. Linn. Bord. **36**: 350. 1883.

Calamaria cubana Kuntze, Rev. Gen. Pl. **2**: 828. 1891-93.

Corm 3-lobed; leaves 20–40, 15–40 cm. long, bright green, firm, of medium fineness, gradually tapering to a point, with membranaceous margin extended 2–5 cm. above sporangium level; brown papery scales sometimes produced from leaf bases; stomata rare, chiefly near tips; peripheral strands 6; ligule short, broad triangular; sporangium oval, 4–7 mm. long, with very narrow velum; megaspores white, 290–400 μ long, closely marked with large round depressed tubercles on each face; microspores 26–30 μ long, tuberculate.

Distribution: western Cuba, Pinao del Rio.

Specimens examined:

Cuba: "in rivulets (on the bottom) of the pinewood, Western Cuba, Pinao del Rio, 1866," *Wright 3912* (Mo. Bot. Gard. Herb., Gray Herb., U. S. Nat. Herb., N. Y. Bot. Gard. Herb.).

This form resembles the *I. velata* series in having large tubercles on the megaspores, which differ, however, in not being restricted to a central group on the apical faces but in covering practically the whole face; furthermore, the tubercles instead of being wart-like and much-raised are depressed. Of the 3-lobed forms, it resembles *I. adspersa* A. Br. in the small megaspores, less than 400 μ, and in the absence of a velum.

9. I. nigritiana A. Br. in Kuhn, Fil. Afr. 196. 1868; Motel. & Vendr. Actes Soc. Linn. Bord. **36**: 388. 1883.

Calamaria nigritiana Kuntze, Rev. Gen. Pl. **2**: 828. 1891-93.

Corm 3-lobed; leaves 12–15, 14–18 cm. long, flexuous, very fine, rigid, pale green, opaque, with numerous stomata and poorly developed peripheral strands or none; sporangia pale, globose; velum very narrow; megaspores small, gray, with a single tubercle on each apical face, placed centrally within the triangle; on the lower face, several smaller, placed variably.

Distribution: Africa, Nigeria, along the Niger River, Nupe.

Description from Kuhn, Motelay and Vendryès, and Sadebeck in Engl. & Prantl.

10. I. adspersa A. Br. in Bory & Dur. Expl. Sci. Alg. *pl. 37. fig. 3.* 1846-49; Milde, Fil. Eur. 286. 1867; Baker, Fern Allies, 129. 1881, and Jour. Bot. **18**: 106. 1880; Motel. & Vendr. Actes Soc. Linn. Bord. **36**: 381. *pl. 11. fig. 5–6.* 1883.

I. setacea Perreymondii Bory, Compt. Rend. Acad. Paris **18**: 1165. 1844, and Flora **27**: 716. 1844.

I. lineolata Dur. in Motel. & Vendr. Actes Soc. Linn. Bord. **36**: 381. 1883.

Calamaria adspersa Kuntze, Rev. Gen. Pl. **2**: 828. 1891-93.

Corm 3-lobed; leaves 9–25, 7–16 cm. long, very slender, filiform, attenuated, with wide membranaceous margin at base extending 1–2 cm. above level of sporangium; bases sometimes persistent as brown scales; stomata common; peripheral strands 4 or more; ligule longer than wide, ovate-acuminate; sporangia oval, 3–5 mm. long, spotted with brown sclerenchyma cells; velum very narrow; megaspores white, sharply angled, 328–400 μ in diameter, with few coarse warts and very prominent commissural ridges; microspores light brown, 27–34 μ long, spinulose, sometimes wing-crested.

Distribution: Algeria.

Specimens examined:

Algeria: Oran, May, 1844, *Durieu* (Mo. Bot. Gard. Herb.); dry flats in field, Oran, 28 April, 1842, *ex Herb. Motelay* (Mo. Bot. Gard. Herb.); near Oran, 12 June, 1844, *Bory* (Gray Herb.); along old route from Figuiers to Oran, 24 April, October, 1852, *Herb. des Flores Européenes* (*Balansa*) *25* (Mo. Bot. Gard. Herb. and Gray Herb.); Plateau du Djebel Santo, near Oran, May, 1857, *Flores Regionales Algeria* (*Weddell*) *16* (U. S. Nat. Herb.); Flora Africae borealis, 1910-1911, Dj. Habibi, *Gandoger* (Mo. Bot. Gard. Herb.); Oran, 1907, *Gandoger* (Mo. Bot. Gard. Herb.); in exsiccated pools, mountain Djebel Santo, near Oran, 14 March, 1876, *Warion 188* (Gray Herb.).

The above species can be readily distinguished from *I. velata* A. Br. by its narrow velum (in contrast to one almost complete), by its narrower leaves, and most markedly by the smaller megaspores, of which the markings resemble more nearly those of *I. Boryana* Dur.

11. I. Boryana Dur. Bull. Soc. Bot. Fr. 8: 164. 1861; Milde, Fil. Eur. 284. 1867; Baker, Fern Allies, 130. 1887, and Jour. Bot. 18: 107. 1886; Motel. & Vendr. Actes Soc. Linn. Bord. 36: 353. *pl. 10. fig. 1–10.* 1883.

Calamaria Boryana Kuntze, Rev. Gen. Pl. 2: 828. 1891-93.

Corm 3-lobed; leaves (10) 15–30, 12–20 cm. long, loosely arranged at base, rather coarse, tapering gradually to apex, with wide membranaceous margin suddenly narrowed a few millimeters above sporangium level; stomata numerous; peripheral strands 6, frequently with accessory strands; ligule deltoid; sporangia subglobose to oblong, 3–8 mm. long, sometimes with brown spots; velum complete or nearly so; megaspores white when dry, dark when wet, 400–640 μ in diameter, marked with few large and scattered smaller warts, sometimes confluent on the basal face to produce very short, irregularly lobed, rounded elevations; microspores reddish-brown, 26–33 μ long, spinulose.

Distribution: France, Landes.

Specimens examined:

France: "Etang de Cazau," Landes, 7 September, 1863, *Durieu* (Mo. Bot. Gard. Herb. and U. S. Nat. Herb.), TYPE; "Etang de St. Julien," Borne, Landes, 31 July, 1863, *Durieu* (Mo. Bot. Gard. Herb.); "Etang de Cazau," near Bordeaux, September, 1860, *Durieu* (Mo. Bot. Gard. Herb., Gray Herb., and N. Y. Bot. Gard. Herb.); Etang de Cazau, near Sanguinet, 3 September, 1860, and 14 July, 1861, *Schultz* (*Durieu*) *778* (N. Y. Bot. Gard. Herb., Mo. Bot. Gard. Herb., and U. S. Nat. Herb.); in field, Etang de Cazau, 4 September, 1861, *Gay* (Gray Herb.); Sanguinet, 5 July, 1863, *Durieu* (Mo. Bot. Gard. Herb.); Sanguinet, 19 July, 1863, *Durieu* (Gray Herb.); Etang de Sanguinet, near Cazau, July, 1868, *Durieu* (N. Y. Bot. Gard. Herb.); Sanguinet (Landes), 23 July, 1900, *Neyraut* (Mo. Bot. Gard. Herb. and Univ. Minn. Herb.); Etang d'Aurelion (Landes), June, 1861, *Foucault,* (Mo. Bot. Gard. Herb.); Etang de Cazau, 17 August, 1890, *Neyraut* (Mo. Bot. Gard. Herb.); near Seignosse (Landes), 2 August, 1891, *Neyraut* (Mo. Bot. Gard. Herb.); Parentis (Landes), 9 July, 1893, *Neyraut* (Mo. Bot. Gard. Herb.); Sanguinet, 27 September, 1860, *Motelay 1903* (U. S. Nat. Herb.); "mixed with Durieu's lacustris,

Lac de Guery, 23–27 August, 1861, Motelay misit," *Herb. Eaton* (Mo. Bot. Gard. Herb.).

12. I. tenuissima Boreau, Bull. Soc. Ind. d'Angers, 269. 1850; Grenier & Godron, Fl. Fr. **3**: 650. 1855-56; Milde, Fil. Eur. 285. 1867; Motel. & Vendr. Actes Soc. Linn. Bord. **36**: 351. 1883; Baker, Fern Allies, 131, 1887, and Jour. Bot. **18**: 107. 1880; Bot. Centralbl. **57**: 246. 1894.

I. Viollaei F. Hy, Jour. de Bot. 8: 96. 1894.

Calamaria tenuissima Kuntze, Rev. Gen. Pl. 2: 828. 1891-93.

Corm 3-lobed; leaves 7–12, 7–12.5 cm. long, 3-angled, erect, slender, gradually tapering from base to apex; stomata fairly common; peripheral strands not evident; ligule small, triangular; sporangia globose, 2–3 mm. long, with velum complete or nearly so; megaspores creamy in color when dry, brown when wet, 400–480 μ in diameter, with few large warts (4 or 5) on upper faces, more on basal (about 13–15); commissural ridges prominent; microspores 25–33 μ long, with numerous long, blunt spines.

Distribution: Province of Riz-Chauvron, Haute-Vienne, France.

Specimens examined:

Central France: Haute-Vienne, without date, *Boreau* (Gray Herb.); Riz-Chauvron, 25 September, 1856, *Schultz* (*Chaboisseau*) *395* (Mo. Bot. Gard. Herb.); Riz-Chauvron, Haute-Vienne, 5 September, 1865, *Schultz* (*Deloynes*) *395b.* (U. S. Nat. Herb.); Riz-Chauvron, September, 1857, *Chaboisseau* (Mo. Bot. Gard. Herb. and Gray Herb.); Riz-Chauvron, Haute-Vienne, 7 September, 1859, *Chaboisseau* (N. Y. Bot. Gard. Herb.); Riz-Chauvron, 20–25 September, 1860, *Chaboisseau 70* (Mo. Bot. Gard. Herb. and Gray Herb.); Riz-Chauvron, 1864, *Motelay* (Mo. Bot. Gard. Herb.); Riz-Chauvron, 8 September, 1865, *Chaboisseau* (Mo. Bot. Gard. Herb.); Etang du Riz-Chauvron, September, 1869, *Durieu* (Gray Herb.); near St. Léomer, Vienne, 7 August, 1893, *Violleau 427* (Mo. Bot. Gard. Herb.); Etang de La Harpe near Loreux (Loir et Cher), 28 July, 1883, *Martin 19* (N. Y. Bot. Gard. Herb.); "La Harpe," Loreux (Loir et Cher), 7 August, 1876, *Le Grand* (N. Y. Bot. Gard. Herb.); St. Léomer, Vienne, August, 1893, *F. Hy*

(Mo. Bot. Gard. Herb.); Riz-Chauvron, August, 1893, *F. Hy* (Mo. Bot. Gard. Herb.).

Germany: with *lacustris,* Wjellingsee, Bütow, Pomerania, *Doms* (Mo. Bot. Gard. Herb.).

The specimen from Pomerania is a single one, which shows undoubted *tenuissima* characters, both in vegetative and reproductive features. It is a question whether it was not placed with the Pomerania material originally through an error. No other stations than those in central France have been brought to light to date, save this distant one, as indicated by a single plant.

Hy's species *I. Viollaei* was based on *I. tenuissima* Bor. specimens which showed brown lines about the sporangium at the base of the leaf. At best, this character would serve only in separating a form. Several American species show in the same stand both pallid and spotted-leaved forms, as *I. melanopoda* Gay & Dur. The species is very closely related to *I. Boryana* Dur., rather than to *I. adspersa,* as Grenier and Godron indicate.

13. I. dubia Genn. Comment. Critt. Ital. (2): 104. 1861; A. Br. Monatsber. K. Akad. Wiss. Berlin, 606. 1863; Milde, Fil. Eur. 282. 1867.

Calamaria dubia Kuntze, Rev. Gen. Pl. 2: 828. 1891-93.

Corm 3-lobed; leaves 18–22 cm. long, yellow-green, soft, fine, narrowly wing-margined at the base; ligule very broadly ovate; weak peripheral strands with no accessories; sporangia completely covered by velum, devoid of colored cells; megaspores 480–560 μ, similar to *I. velata,* but with commissures somewhat smaller and sharper, causing sharper angles in joining the equator; warts smaller and less distinct; microspores of two sorts, some similar to *I. velata,* others with exospore extended into wing, cristate and lobed on back.

Distribution: Island of Magdalena, Sardinia.

Description from Braun and Milde.

14. I. olympica A. Br. in Milde, Fil. Eur. 285. 1867; Motel. & Vendr. Actes Soc. Linn. Bord. **36**: 362. 1883.

Calamaria olympica Kuntze, Rev. Gen. Pl. **2**: 828. 1891-93.

Corm 3-lobed; leaves 3–5 cm. long, light green, ½ mm. broad above sheath; stomata numerous; peripheral strands less devel-

oped than in *I. Boryana* and *I. tegulensis;* sporangia small, 2 mm. long, without thickened cells; velum covering 1/3–2/3 of sporangium; megaspores white, 360–440 μ, covered with unequal hemispherical warts on the basal face, with smaller more numerous tubercles, often inconspicuous, on the apical faces; microspores 30 μ long, 20 μ wide, spinulose.

Distribution: small pools in granite plains of Olympus near Brussa of Bithynia.

Description based on Milde's data.

15. I. velata A. Br. in Bory & Dur. Expl. Sci. Alg. *pl. 37. fig. 1.* 1846-49; Genn. Comment. Critt. Ital. 103. 1861; A. Br. Monatsber. K. Akad. Wiss. Berlin, 602. 1863; Milde, Fil. Eur. 280. 1867; Franchet, Fl. Loir et Cher, 747. 1885, and Bull. Soc. Bot. Fr. **31**: 349. 1884; Motel. & Vendr. Actes Soc. Linn. Bord. **36**: 384. *pl. 15. fig. 8–9.* 1883.

I. decipiens Bory, Flora **29**: 719. 1846.

I. setacea var. *Delilei* Bory, Compt. Rend. Acad. Paris **18**: 1165. 1844, and Flora **27**: 716. 1844.

I. Chaboissaei Nym. Consp. Fl. Eur. 871, name only.

Calamaria longissima Kuntze, Rev. Gen. Pl. 2: 828. 1891-93.

Corm 3-lobed; leaves 5–30, sometimes 40, 8–24 cm. long, tapering to apex, rather fine, with wide membranaceous border at base extending ½ cm. above sporangium level; base of leaf sometimes persisting as a brown papery scale; stomata numerous; peripheral strands usually 6, rarely only 4, frequently with weaker accessory strands in variable number; ligule triangular lanceolate; sporangium 3–5 mm. long, nearly (4/5) to completely covered by velum; megaspores 420 (360) –580 μ in diameter with few large warts on upper faces (3–10), and with mixed large and small warts on basal face; microspores red-brown, 26–33 μ long, densely spinulose.

Distribution: Sicily, Corsica, Algeria.

Specimens examined:

Sicily: near Misilmer, 24 May, 1856, *Pl. Siculae 242* (*Huet de Pavillon*) (Mo. Bot. Gard. Herb.).

Corsica: near Bonifacio, on granite, rare, April, 1893, *Reverchon* (Mo. Bot. Gard. Herb.); Corsica, *Rabenhorst Crypt. Vasc. Eur.* (*Reveliere*) *105* (N. Y. Bot. Gard. Herb.).

Algeria: wet places near Bona, about 1860, *LeTourneux* (Mo. Bot. Gard. Herb.); ponds of Chaïba near Coléah, 18 April, 1859, *Herb. Font. norm. (Clauson) 99* (Gray Herb.); Daïa, 29 April, 1859, *Herb. Font. norm. (Clauson) 99 bis* (Gray Herb.); Lac de Ouled Dieb., between Bone and LaCalle, *LeTourneux* (Gray Herb.); swamps, Boudom, 12 April, 1861, *Frag. Fl. Alg. Exsic. 499 (Bourlier)* (U. S. Nat. Herb.); mares de Bou Zegart between Oued Khamis and Djebel Azieb Dahra, Prov. Oran, 20 May, 1875, *Warion Pl. Atl. Sel. (Cosson) 189* (Gray Herb. and U. S. Nat. Herb.); Maison Cairee, April, 1878, *Debeaux* (N. Y. Bot. Gard. Herb.); without definite locality, 1906, *Gandoger* (Mo. Bot. Gard. Herb.).

15a. Forma **longissima** Pfeiffer, comb. nov.

I. longissima Bory & Dur. Compt. Rend. Acad. Paris 18: 1165. 1844.

I. velata var. *longissima* A. Br. in Bory & Dur. Expl. Sci. Alg. *pl. 37. fig. 2.* 1846-49.

Differs from the species in the greater leaf length, as much as 50–65 cm. in the larger plants. There is a tendency toward a smaller number of leaves (8–12).

Distribution: Algeria.

Specimens examined:

Algeria: LaCalle, May, 1844, *Durieu* (Mo. Bot. Gard. Herb.); LaCalle, May, 1844, *Bory* (Gray Herb.); inundated prairies, 24 June, 1844, *Motelay* (Mo. Bot. Gard. Herb.); LaCalle, 1861, *Durieu* (Gray Herb.); LaCalle, June, 1884, *Debeaux* (U. S. Nat. Herb.).

From the presence of persistent papery brown bases of leaves in some specimens it seems likely that this form may assume practically a terrestrial habit, as in *I. Nuttallii* A. Br. and *I. Butleri* Engelm.

The species shows great variability, and its close allies, differing from it in sometimes inconspicuous features, are correspondingly difficult to delimit. Braun and Engelmann were eventually inclined to consider *I. Boryana, I. tenuissima, I. Perralderiana, I baetica, I. tegulensis, I. dubia* and *I. longissima* as forms or subspecies of *I. velata.* There is doubtless a complex here, which properly should be solved by those able to work with an abun-

dance of living material of the forms concerned. A relatively small representation of dried material is inadequate for the problem. *I. longissima* is reduced here to a form since there seems no basis for separation but leaf length. *I. Perralderiana* is reduced to a variety, differing from the species in having more slender leaves and smaller megaspores. The other species are retained in their present rank with the knowledge that they might readily be reduced to varieties, if geographical limitations were not distinct.

15b. Var. Perralderiana Pfeiffer, comb. nov.

I. Perralderiana Dur. & LeTourn. in Kralik, Pl. Alg. Exsic. 157; Milde, Fil. Eur. 282. 1867; Kuhn, Fil. Afr. 196. 1868; Baker, Jour. Bot. 18: 107. 1880, and Fern Allies, 130. 1887; Motel. & Vendr. Actes Soc. Linn. Bord. 36: 354. *pl. 11. fig. 7, 8, 9.* 1883.

Calamaria Perralderiana Kuntze, Rev. Gen. Pl. 2: 828. 1891-93.

Like the species in habit except for very fine leaves; megaspores 380–475 μ in diameter, marked with a few large warts and many smaller ones; microspores 26–33 μ long, finely, densely spinulose, sometimes crested.

Distribution: Algeria.

Specimens examined:

Algeria: pool of the fountain of Aïn Sumta, by the gorges Akfadou, eastern Kabylie, 1 August, 1861, *Cosson* (Gray Herb.), TYPE; "cultivated by Durieu at Jardin de Botanique de Bordeaux, coming from Jurajura", 11 July, 1871, *LeTourneux* (Mo. Bot. Gard. Herb.).

16. I. tegulensis Genn. Comment. Critt. Ital. (2): 106. 1861; Milde, Fil. Eur. 283. 1867; A. Br. Monatsber. K. Akad. Wiss. Berlin, 608. 1864; Fl. Ital. 1867; Baker, Jour. Bot. 18: 107. 1880; Motel. & Vendr. Actes Soc. Linn. Bord. 36: 363. *pl. 11. fig. 3–4.* 1883.

I. Tiguliana Genn. Comment. Critt. Ital. (1): 42. 1861.

Calamaria tegulensis Kuntze, Rev. Gen. Pl. 2: 828. 1891-93.

Corm 3-lobed; leaves 5–20, 20–30 cm. long, yellow-green, very fine, erect, with narrow membranaceous margins little elongated

above sporangium level; stomata common; peripheral strands 6; ligule small triangular; sporangia oval, 4–6 mm. long, almost or completely covered by velum; megaspores white, 400–520 μ (rarely 600) in diameter, with large well-rounded tubercles on all faces, sometimes with scattered small additional warts on upper faces; commissural and equatorial ridges frequently nodulose; microspores fawn-colored, 26–33 μ long, conspicuously spinulose, sometimes slightly crested.

Distribution: Sardinia.

Specimens examined:

Sardinia: submersed in aqueducts, near Pula, 22 May, 1863, *Ascherson & Reinhardt* (Mo. Bot. Gard. Herb.); Pula, June, 1863, *Ascherson & Reinhardt* (Mo. Bot. Gard. Herb. and Gray Herb.); Pula, June, 1863, *Ascherson* (N. Y. Bot. Gard. Herb.).

This species is one of the forms very closely related to *I. velata* A. Br. It may be distinguished partly by greater length of leaves, which are finer, and partly by the tendency toward smaller megaspores.

17. I. alpina Kirk, Trans. N. Z. Inst. 7: 377. *pl. 25.* 1875; Baker, Fern Allies, 127. 1887, and Jour. Bot. 18: 70. 1880; Motel. & Vendr. Actes Soc. Linn. Bord. 36: 368. 1883.

Calamaria alpina Kuntze, Rev. Gen. Pl. 2: 828. 1891-93.

Corm 3-lobed; leaves 10–50, 10–40 cm. long, dark green, stout, rigid, tapering to a point, with a wide membranaceous margin narrowed immediately above sporangium; stomata present but not numerous; peripheral strands lacking; ligule short, ovate-triangular; sporangium oblong, 5–7, rarely 9, mm. in length; velum complete; megaspores white when dry, brown-black when wet, 400–520 μ (rarely only 320) in diameter, chiefly smoothish, sometimes lightly marked with large tubercles, few in number; microspores rusty-brown, 24–31 μ in length, with numerous spines.

Distribution: New Zealand.

Specimens examined:

New Zealand: Lake Guyon, So. Isl., without date, *Kirk* (N. Y. Bot. Gard. Herb.); Lake Guyon, Nelson, alt. 3000 ft., *Kirk 239* (U. S. Nat. Herb. and Gray Herb.); Lake Guyon, Nel-

son, *Kirk 136* (U. S. Nat. Herb.); Lake Guyon, *Kirk* (Mo. Bot. Gard. Herb.); Lake Rotoiti, alt. 1800 ft., January, 1881, *Cheeseman 56* (N. Y. Bot. Gard. Herb.); Lake Rotoiti, alt. 1800 ft., 1 January, 1881, *Cheeseman* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.); Lake Guyon, 3000 ft., *Hector* (Gray Herb.); Lake Rotoiti, Nelson, January, 1898, *Cheeseman* (Gray Herb.).

Kirk's material from Lake Guyon shows rather shorter, stouter habit in the leaves, which do not exceed 17 cm. in any case. Cheeseman's material derived from Lake Rotoiti invariably shows longer leaves, from 25–40 cm., coarse, but appearing more flexuous. Since most of the material is unfortunately lacking in dates, it is impossible to tell whether the difference in size is to be related to seasonal change, ecological factors, or morphological variation. All material is therefore included under the species.

18. I. Kirkii A. Br. Monatsber. K. Akad. Wiss. Berlin, 2. 1869; Kirk, Trans. N. Z. Inst. 2:107 *pl. 7*. 1875.; Baker, Fern Allies, 127. 1887, and Jour. Bot. **18**: 69. 1880; Motel. & Vendr. Actes Soc. Linn. Bord. **36**: 390. 1883.

Calamaria Kirkii Kuntze, Rev. Gen. Pl. 2: 828. 1891-93.

Corm 3-lobed; leaves 5–15, 7–13 cm. long, medium slender, rather abruptly attenuate at the tip to a very long fine setaceous apex; stomata rare, even at tip; peripheral strands lacking; ligule short, triangular-ovate; sporangia globose, 2–3 mm. in length, completely covered by velum; megaspores white, 460–580 μ in diameter, marked on all surfaces with numerous closely set small tubercles, with very slight tendency to confluence on the basal face; microspores small, 17–25 μ, smooth.

Distribution: mountain lakes in New Zealand.

Specimens examined:

New Zealand: Whangape Lake, *Kirk* (Mo. Bot. Gard. Herb., Gray Herb., and U. S. Nat. Herb.), COTYPE; Whangape Lake, *Hector* (Gray Herb.); Lake Tekapo, Canterbury, South Isl., 7 January, 1883, *Cheeseman* (U. S. Nat. Herb.); ponds near Lake Tekapo, Canterbury Alps, alt. 2000 ft., *Cheeseman* (Mo. Bot. Gard. Herb.); Lake Whangape, 1882, *ex herb. Martindale* (*Cheeseman coll?*) (Mo. Bot. Gard. Herb.); Lake Whangape, Waikato, N. Isl., *Cheeseman* (Mo.

Bot. Gard, Herb.); Whangape Lake, January, 1879, *Cheeseman* (Gray Herb.).

19. I. Gunnii A. Br. in Herb. Hooker. 1866; A. Br. Monatsber. K. Akad. Wiss. Berlin, 535. 1868; Baker, Fern Allies, 124. 1887, and Jour. Bot. 18: 66. 1880; Motel. & Vendr. Actes Soc. Linn. Bord. 36: 347. 1883.

Isoetes sp. Hooker, Fl. Tasm. 2: 158. 1860.

I. lacustris (L.) Rodway, Tasm. Fl. 279. 1903.

Calamaria Gunnii Kuntze, Rev. Gen. Pl. 2: 828. 1891-93.

Corm 3-lobed; leaves 30–50, 3–13 cm. long, stout, tough, abruptly-pointed at tip, with wide membranaceous border at base, continued upward 4–6 times the length of sporangium; stomata and peripheral strands none; ligule short, with cordate base; sporangium oblong, 3–6 mm. long, marked with brown cells, with velum lacking; megaspores ashy or light brown when dry, dark shining brown when wet, 600–800 μ in diameter, marked with small distant tubercles, rarely elongated in one diameter, or somewhat ridge-like; microspores brown, 29–36 μ long, chiefly spinulose.

Distribution: Tasmania, mountain lakes.

Specimens examined:

Tasmania: Lake Fenton, Mt. Field, 3000 ft. alt., 1869, *v. Mueller* (N. Y. Bot. Gard. Herb.); Mt. Field, *Rodway* (Mo. Bot. Gard. Herb.); Hartz Mts., 1918, *Rodway* (Mo. Bot. Gard. Herb.); Hobart, 1918, *Rodway* (Mo. Bot. Gard. Herb.).

In this short coarse plant, the upper half of the leaves usually appears a dark green, the base brown, in herbarium specimens. The bulb formed by the sporangia is apt to be 3–4 cm. in diameter. According to F. v. Mueller, the leaves are rigid enough so that the term "water-porcupine" seemed fitting for plants growing in Lake Fenton on Mt. Field. He reported corms as large as one's fist, and a habit of growth in groups that resulted in a polster.

All of the material examined at Mo. Bot. Gard. in 1918 was obtained through the courtesy of L. Rodway of Hobart, Tasmania, who is presumably the collector.

20. I. Drummondii A. Br. Monatsber. K. Akad. Wiss. Berlin, 593. 1863, and 542. 1868; Baker, Jour. Bot. **18**: 70. 1880, and Fern Allies, 128. 1887; Motel. & Vendr. Actes Soc. Linn. Bord. **36**: 319. *pl. 13. fig. 4–5.* 1883.

Calamaria Drummondii Kuntze, Rev. Gen. Pl. **2**: 828. 1891-93.

Corm 3-lobed; leaves 18 or fewer, 3–7 cm. long, somewhat loosely arranged, coarser than *I. Muellerii* and *I. tripus*, bright green; stomata present; no peripheral strands; ligule very short, cordate-triangular; sporangium rounded, without sclerenchyma cells; velum lacking; megaspores whitish when dry, dark brown when wet, 340–470 μ in diameter, marked with numerous (36–40) minute tubercles, distinct on apical faces, sometimes confluent in meandriniform ridges on basal face; microspores 30–39 μ long, violet-ashy, short denticulate-muricate.

Distribution: Australia: Swan River.

Specimens examined:

Australia: wet rocks, Toodyay, coll. *O. W. F.* (N. Y. Bot. Gard. Herb.); Tea Tree Gully, South Australia, 13 October, 1917, *Osborn* (Mo. Bot. Gard. Herb.); National Park, Belair, 27 September, 1917, *Osborn* (Mo. Bot. Gard. Herb.); Echunga, South Australia, 1 September, 1921, *Osborn* (Mo. Bot. Gard. Herb.).

The plants of the first collection were small, consisting of 5 or 6 fine leaves, about 3 cm. long, bearing sporangia 2–2.5 mm. in length, without velum. The megaspores were 360–470 μ in diameter, chiefly 430 μ, and showed rather close anastomosing ridges on basal face. The microspores, densely spinulose, 32–39 μ in length, were brown in the mass, with a violet cast.

21. I. amazonica A. Br. acc. Kuhn in Martius, Fl. Bras. 1^2: 647. *pl. 79. fig. 5–6.* 1884; Baker, Jour. Bot. **18**: 109. 1880, and Fern Allies, 133. 1887; Motel. & Vendr. Actes Soc. Linn. Bord. **36**: 351. 1883.

Calamaria amazonica Kuntze, Rev. Gen. Pl. **2**: 828. 1891-93.

Corm 3-lobed; leaves 10–12, 5–7 cm. long, somewhat rigid; stomata and accessory peripheral strands present; ligule short, triangular; sporangium small (2–2.5 mm.), lacking velum; megaspores white to ashy, 430–510 μ in diameter, with numerous warts, single or confluent into verrucose ridges; microspores 33–40 μ, finely tuberculate.

Distribution: Brazil.

Specimens examined:

Brazil: near Santarem, Para, September, 1850, *Spruce* (Gray Herb.), TYPE?

In the Mo. Bot. Gard. Herb., there are some immature specimens from "ditches of the Agulhas Negras, Serra do Itatiaia, State of Santa Catharina, Brazil, Rio de Janeiro, March, 1894. E. Ule." These consist of 4 or 5 leaves, 2–3 cm. in length, rather soft, light green, with fairly numerous stomata and no evident peripheral strands. There is fragmentary material of megaspores, almost smooth or lightly marked with wavy prominences; the diameter appears to be 400–468 μ. The microspores, 23–27 μ long, are smooth or with minute tubercles. The form was placed by Eaton in *I. amazonica*. Such fragmentary, doubtfully mature material is difficult to place with certainty. The geographic range is great if this form occurs in these two states at opposite ends of Brazil in different river systems.

Quite different specimens of Dusen's collecting from the same station seem to accord better with *I. Martii* A. Br., though again the spores are immature.

22. I. Gardneriana A. Br. Verh. Bot. Ver. Brandenb. **4**: 330. 1862; Mett. Fil. Lechl. Fasc. **11**: 36; Kuhn in Martius, Fl. Bras. 1^2: 647. *pl. 79. fig. 1–4.* 1884; Motel. & Vendr. Actes Soc. Linn. Bord. **36**: 349. 1883; Baker, Jour. Bot. **18**: 110. 1880.

Calamaria Gardneriana Kuntze, Rev. Gen. Pl. 2: 828. 1891-93.

Corm 3-lobed, 3–3.5 cm. broad; leaves erect, coarse, firm, 30–32 cm. long, attenuate at apex, somewhat obtuse, obscurely quadrangular; peripheral strands 4, strong; stomata present; ligule triangular, obtuse, hardly half as long as the sporangium; velum incomplete; sporangium dark, about 10 mm. long; megaspores 540–700 μ in diameter, dark brown whether wet or dry, with number of fine tubercles, distinct on all faces; microspores very smooth, white, 35 μ in length.

Distribution: Province of Goyaz in Brazil; Paraguay.

Description from Braun and Kuhn.

23. I. elatior F. Muell. in A. Br. Linnaea **25**: 722. 1852, and Monatsber. K. Akad. Wiss. Berlin, 536. 1868; Motel. & Vendr. Actes Soc. Linn. Bord. **36**: 348. 1883.

Isoetes tasmanica F. Muell. in Dur. Bull. Soc. Bot. Fr. **11**: 104. 1864.

Calamaria elatior Kuntze, Rev. Gen. Pl. **2**: 828. 1891-93.

Corm 3-lobed; leaves numerous and long, flexuous; stomata and peripheral strands lacking; ligule cordate, elongated; sporangia dark, practically black with sclerenchyma cells; velum lacking; megaspores white when dry, black when moist, 480–650 μ in diameter, marked with minute, very dense tubercles all over surface, confluent into ridges; microspores coffee-brown, (28) 32–35 μ in length, densely muricate.

Distribution: Tasmania.

Specimen examined:

Tasmania: *Archer* (Gray Herb.).

This sheet is marked "*I. lacustris.* Tasmania. Coll. R. C. Gunn." to which Engelmann, Feb. 1880, made note, "Not collected by Gunn. Identical with *I. elatior* F. Muell. *Archer* legit."

The megaspores are 570–650 μ in diameter, with minute elevations above, crinkly in effect, but not anastomosing on the basal face. The microspores range from 28 to 34 μ, and are covered with numerous fine spines. The leaves are 14–18 in number, about 30 cm. long, and lack a velum.

Description in part from Braun.

24. I. Muelleri A. Br. Monatsber. K. Akad. Wiss. Berlin, 541. 1868; Baker, Jour. Bot. **18**: 69. 1880, and Fern Allies, 127. 1887; Motel. & Vendr. Actes Soc. Linn. Bord. **36**: 389. 1883.

I. tenuissima F. Muell. (non Boreau) Motel. & Vendr. Actes Soc. Linn. Bord. **36**: 389. 1883.

Calamaria Muelleri O. K. Rev. Gen. Pl. **2**: 828. 1891-93.

Corm 3-lobed, with loose bulb of leaves; leaves few, 7 cm. long, narrow, attenuate, pale green, diaphanous; stomata present; peripheral strands lacking; ligule cordate-ovate; velum complete, closed, pale; sporangium becoming dark, with all epidermal cells thickened, some light, some very dark; megaspores 330–390 μ, white or ashy white, marked with less numerous (20–25 tubercles per face) unequal tubercles, even confluent into branching ridges.

Distribution: Eastern Australia, wet places at Rockhampton.

25. I. histrix Bory & Dur. Compt. Rend. Acad. Paris **18**: 1167. 1844; A. Br. in Bory & Dur. Expl. Sci. Alg. 36. *fig. 1.* 1846-49; Milde, Fil. Eur. 288. 1867; Kuhn, Fil. Afr. 195. 1868; Baker, Jour. Bot. **18**: 110. 1880, and Fern Allies, 134. 1887; Motel. & Vendr. Actes Soc. Linn. Bord. **36**: 394. 1883.

Calamaria Hystrix Kuntze, Rev. Gen. Pl. **2**:828. 1891-93.

I. Delalandei Lloyd, Fl. Ouest. Fr., ed. 1, 728. 1854.

Cephaloceratodon hystrix Genn. Comment. Critt. Ital. (3): 111. 1862.

Corm 3-lobed; leaves 9–22, 5–10 cm. long, linear, firm, with membranaceous margin disappearing at sporangium level; bases of leaves persistent as hard brown horny structures, with central short broad tooth and two longer lateral spine-like teeth, producing an exaggerated effect of size at the corm level through persistence from one season through succeeding ones; stomata numerous; peripheral strands 4, strongly developed; ligule ovate-triangular; sporangia 4–6 mm. long, completely covered by velum; megaspores white, 400–560 (600) μ in diameter, closely marked with small tubercles or warts, becoming somewhat confluent, especially on the basal surface; microspores brown, 25–33 μ long, spinulose.

Distribution: Algeria, islands of Mediterranean, Italy, France.

Specimens examined:

Algeria: dry sands, hills of LaCalle, March, 1841, *Durieu* (Mo. Bot. Gard. Herb.), TYPE; dry hills, LaCalle, 30 March, 1841, *Durieu* (Gray Herb.); near Mascara, May, 1844, *Bory* (Gray Herb.); Mascara, May, 1841, *Durieu* (Mo. Bot. Gard. Herb.); near Mascara, 14 September, 1864, *Warion* (U. S. Nat. Herb.); "Telegraph, infer Alger," April, 1856, *Guthnik?* (N. Y. Bot. Gard. Herb.); in wet sandy places at Sidi-Dako, near Mascara, 28 April, 1875, *Warion Pl. Atl. Sel. 187* (*Kralik*) (U. S. Nat. Herb. and Gray Herb.); wet sands of the plain of Chearfa, Mostaganem, Prov. Oran, 19 May, 1875, *Cosson* (Gray Herb.); Dj. Ouach. Prov. Constantine, 26 May, 1880, *Cosson* (Gray Herb.); LaCalle, April, 1884, *Debeaux* (U. S. Nat. Herb.); Bône, 1906, *Gandoger* (Mo. Bot. Gard. Herb.).

Tunis: north of Aïn-Draham, 4 July, 1883, *Cosson et al.* (Gray Herb.).

Corsica: Bonifacio, 21 April, 1866, *Mabille* (Mo. Bot. Gard.

Herb.); Porto Vecchio, April and May, *Revelière* (U. S. Nat. Herb. and N. Y. Bot. Gard. Herb.).

Phrygia: dry hills near village Kaiageul, S. of Ouchak, 30 May, 1857, *Balansa 849* (U. S. Nat. Herb.).

Crete: Crete, 12 March, 1882, *Reverchon* (Mo. Bot. Gard. Herb. and U. S. Nat. Herb.); Crete, *ex herb. Ball* (Gray Herb.).

Sardinia: Caprera I., granitic soil, 15 May, 1905, *Vaccari 503* (Gray Herb.); Bancamino, 3 June, 1881, *Reverchon* (N. Y. Bot. Gard. Herb.).

Italy: Castagnolo, 3 May, 1865, *Caruel* (Mo. Bot. Gard. Herb.); wet fields, Castagnolo, Pisa, 28 November, 1862, *Ball* (Gray Herb.).

France: Isle d'Yeu, Vendée, May, 1880, *Grand-Marais* (N. Y. Bot. Gard. Herb.); near the sea coast on Isle d'Yeu, Vendée, May, 1883, *Grand-Marais* (Mo. Bot. Gard. Herb.); "mare de Rochaute," near Agde, 5 October, 1846, *Fabre* (Gray Herb.); Ile de Houat, Morbihan, April, 1853, *Lloyd 198* (N. Y. Bot. Gard. Herb.).

25a. Forma **subinermis** Dur. Bull. Soc. Bot. Fr. 8: 164. 1861.

I. histrix f. *desquamata* A. Br. Monatsber. K. Akad. Wiss. Berlin, 617. 1864.

I. hystrix Wolsey, New Phytol. II. **5**: 45. 1861.

Cephaloceratodon gymnocarpum Genn. Comment. Critt. Ital. (3): 113. 1862.

I. histrix var. *scutellata* A. Br. acc. Motel. & Vendr. Actes Soc. Linn. Bord. **36**: 400. 1883.

The form differs from the species in the persistent structure resulting from the leaf base; the former lacks the lateral horns or teeth. There is a wider range in megaspore size, with a slight tendency toward greater size, and the confluence of the tubercles is sometimes quite pronounced.

Phrygia: rocky hills above the village of Kaiageul, s. of Ouchak, 30 May, 1857, *Balansa 1327* (Gray Herb.).

Sardinia: near Pula, at foot of Mt. Santo, in wet declinities, inundated in winter, alt. 30 m., granitic soil, 23 March, 1912, *Fiori & Béguinot 1607* (Gray Herb.); I. Caprera, July, 1863, *Ascherson & Reinhardt* (Mo. Bot. Gard. Herb.); I. of Caprera, 11 June, 1863, *Ascherson & Reinhardt* (Gray Herb.).

France: near Cazau (Landes), 5 July, 1861, *ex herb. norm. F. Schultz* (*Durieu*) *781* (U. S. Nat. Herb.); "southern France," July, 1861, *Durieu* (Gray Herb. and N. Y. Bot. Gard. Herb.); near Grasse, Alpes Maritimes, 1 April, 1891, *Mouillefarines* (U. S. Nat. Herb.); pools near Cazau, Landes, 29 June, 1862, *Durieu* (Mo. Bot. Gard. Herb.); sandy pastures near Étang and village of Cazau, Landes, 1861, *Durieu* (Mo. Bot. Gard. Herb.); dry sand near Cazau, September, 1861, *Durieu* (Gray Herb.); near the sea-coast, on the Ile d'Yeu Vendée, May, 1883, *Grand-Marais* (Mo. Bot. Gard. Herb.); Gironde, August, 1891, *Motelay* (Mo. Bot. Gard. Herb.); Cazau (Gironde), along railroad near station of Cazau, Hameau, 20 May, 1900, *Neyraut* (Mo. Bot. Gard. Herb. and Univ. Minn. Herb.); Mios, Gironde, 11 July, 1897, *Neyraut* (Mo. Bot. Gard. Herb. and N. Y. Bot. Gard. Herb.).

Guernsey: L'Aucresse, 15 June, 1884, *Hanbury 1656* (N. Y. Bot. Gard. Herb.).

The plants of Neyraut collected at Mios are unusual in large number of leaves (up to 50), but appear to be the form with a poor development of the scaly bases.

26. I. Nuttallii A. Br. in Engelm. Am. Nat. 8: 215. 1874; Baker, Jour. Bot. 18: 105. 1880; Engelmann, Trans. St. Louis Acad. Sci. 4: 388. 1882; Motel. & Vendr. Actes Soc. Linn. Bord. 36: 375. 1883; Macoun, Cat. Canad. Pl. pt. 4: 293. 1888; Piper, Contr. U. S. Nat. Herb. **11**: 88. 1906.

I. opaca Nuttall in Engelm. Trans. St. Louis Acad. Sci. 4: 388. 1882.

I. Suksdorfii Baker, Fern Allies, 132. 1887.

Calamaria Nuttallii Kuntze, Rev. Gen. Pl. 2: 828. 1891-93.

Corm slightly 3-lobed; leaves 13–60, 8–17 cm. long, 3-angled, very slender, firm, erect, light green, with membranaceous margins not extended beyond sporangium level; stomata numerous; peripheral strands 3 (sometimes 2 dorsal lacking); ligule small, triangular; sporangia oblong, 4–7 mm. long, completely covered by velum; megaspores white, (320) 400–528 (600) μ in diameter, densely covered by small, usually glistening, distinct papillae on faces between prominent commissural ridges, or rarely smooth; microspores brown, 25–30 μ in length, papillose.

Distribution: California, Oregon, Washington, Vancouver.

Specimens examined:

California: Mt. Tamalpais, Marin Co., 13 June, 1892, *Palmer 2355* (U. S. Nat. Herb.); Tamalpais, June, 1891, *Brandegee* (N. Y. Bot. Gard. Herb.); Mt. Tamalpais, Marin Co., 13 June, 1892, *Mrs. Brandegee* (Mo. Bot. Gard. Herb. and Univ. Minn. Herb.); Mt. Tamalpais, Marin Co., near the big spring on trail to Larsens, 28 June, 1896, *Miss Eastwood* (Mo. Bot. Gard. Herb.); Pine Ridge, Fresno Co., 25 May, 1901, *Thompson* (Mo. Bot. Gard. Herb.); Soquel Point, between Santa Cruz and Capitola, 28 May, 1902, *Mrs. C. H. Thompson* (Mo. Bot. Gard. Herb.); Soquel Point, Santa Cruz, summer, 1903, *Thompson* (Mo. Bot. Gard. Herb.); San Diego, 6 March, 1895, *Brandegee* (Mo. Bot. Gard. Herb.); Glacier Point Meadows, edges of pools in black mucky soil, alt. 7100 ft. (Canadian Life Zone), 6 July, 1914, *Smiley 492* (Gray Herb.); Tuolumne Meadows, pools back of Muir Lodge, Yosemite, alt. 8500 ft. (Canadian Life Zone), 13 August, 1916, *Smiley 747* (Gray Herb.); Coste Madera, June, 1887, *Curran* (N. Y. Bot. Gard. Herb.); partially submerged in sluggish stream, Williams Ranch, Tuolumne Co., 14 June, 1895, *Blasdale* (N. Y. Bot. Gard. Herb.).

Oregon: low pondy places and on high banks in springy situations in Willamette Valley, Salem, Silverton, etc., June and July, 1871, *Hall 693* (Mo. Bot. Gard. Herb., Gray Herb. and U. S. Nat. Herb.); low grassy places, Oregon, 1871, *Hall* (Gray Herb.); "terrestrial, under scrub-oaks," Woodburn, 1 June, 1882, *Thos. J. Howell* (Mo. Bot. Gard. Herb. and U. S. Nat. Herb.); on springy soil and in water near Milwaukee, July, 1880, *J. Howell & Thos. J. Howell 303* (Gray Herb.); on damp springy soil and in water, near Milwaukee, July, 1880, *J. Howell* (Gray Herb.); Oregon, 1886, *T. J. Howell 613* (Gray Herb.); Gladstone, 14 July, 1894, *T. J. Howell 1526* (Mo. Bot. Gard. Herb., U. S. Nat. Herb., and Univ. Minn. Herb.); in shallow pool near south fall, Silver Creek Falls, Marion Co., 29 May, 1921, *Nelson (Peck) 3737* (U. S. Nat. Herb.).

Washington: Columbia River 183-, *Nuttall* (Mo. Bot. Gard. Herb.), TYPE?; springs and meadows, W. Klickitat Co., May, August, 1881, *Suksdorf* (Mo. Bot. Gard. Herb. and U.

S. Nat. Herb.); springs and meadows, W. Klickitat Co., May and September, 1886, *Suksdorf* (N. Y. Bot. Gard. Herb.); meadows and springy places, Columbia River, 12 March and September, 1886, *Suksdorf 917* (Mo. Bot. Gard. Herb. and U. S. Nat. Herb.); on damp ground, Falcon Valley, 16 June, 1890, *Suksdorf 2373* (Mo. Bot. Gard. Herb.); springy places near Bingen, W. Klickitat Co., 5 June, 1894, *Suksdorf 917* (Mo. Bot. Gard. Herb.); wet ground on mountain slopes near the Columbia River, W. Klickitat Co., 3 August, 1894, *Suksdorf 2364* (Mo. Bot. Gard. Herb.); on meadows, Falcon Valley, Klickitat Co., 17 July, 1896, *Suksdorf 2614* (Mo. Bot. Gard. Herb.); on low damp ground, Falcon Valley, W. Klickitat Co., 24 June, 1897, *Suksdorf 2615* (Mo. Bot. Gard. Herb.); on wet ground near Bingen, 14 April, 1904, *Suksdorf 4443* (Mo. Bot. Gard. Herb.).

Vancouver Island: Nanaimo, 13 July, 1887, *John Macoun 14219a, 14219c* (Gray Herb.); vicinity of Nanaimo, 3 July, 1908, *John Macoun 86378* (Gray Herb. and N. Y. Bot. Gard. Herb.); Nanaimo, *John Macoun* (Mo. Bot. Gard. Herb.); vicinity of Victoria, 10 June, 1893, *John Macoun 533* (Gray Herb.).

The peripheral strands are usually three in number at the angles of the 3-sided stem; of these three, the dorsal are the weakest, and in some cases, fail to appear. There is variation as to persistence of bases of leaves. Many specimens show dark brown horny bases (as long as the sporangium) surmounted by three minute teeth, of which the central is slightly longer than the lateral ones. There is variation in the megaspore character in that, though most are rather evidently marked, some are almost smooth.

27. I. Orcuttii Eaton, Fern Bull. 8: 13. 1900.

I. Nuttallii var. *Orcuttii* Clute, Fern Allies, 253. 1905.

Corm slightly 3-lobed; leaves 6–14 (or even 20), 2–6.5, rarely 10, cm. long, fine, erect, triangular, with narrow membranaceous margin only at base; stomata present; peripheral strands none or 2, weakly developed; ligule triangular; sporangia orbicular to slightly elongated, 2–5 mm. long, completely covered by velum; megaspores gray at maturity, brownish when wet, 216–360 μ, rarely 480 μ, in diameter, closely marked with numerous small

indistinct papillae or almost smooth, glistening; microspores 21–27 μ, rarely 29 μ, in length, chiefly spinulose, sometimes smooth.

Distribution: California, Lower California.

Specimens examined:

California: mesas in low depressions, San Diego, 7 June, 1884, *Orcutt 1242* (Mo. Bot. Gard. Herb., Gray Herb., and U. S. Nat. Herb.), TYPE; 3 mi. northeast of Clovis, Fresno Co., 16 February, 1902, *Mr. & Mrs. C. H. Thompson* (Mo. Bot. Gard. Herb.); meadow, Soquel Point, Santa Cruz, 10 and 29 April, 1900, *C. H. Thompson* (Mo. Bot. Gard. Herb.); Soquel Point near Capitola, Santa Cruz Co., 6 March, 1901, *Mrs. C. H. Thompson* (Mo. Bot. Gard. Herb.); El Cajon, April, 1895, *Brandegee* (Mo. Bot. Gard. Herb.); 5 mi. west of Stanford University, near Los Francos Creek, 13 April, 1903, *Thompson* (Mo. Bot. Gard. Herb.); near Upland, growing in desiccating pools on clay mesa, 8 March, 1917, *Ivan Johnson* (U. S. Nat. Herb.); mesas, San Diego Co., 14 May, 1903, *Orcutt* (U. S. Nat. Herb.); in "Hog Wallows, dry as early as 10 March, usually wet until May 1," 1889, *Curran* (N. Y. Bot. Gard. Herb.); Antioch, Contra Costa Co., 7 April, 1895, *Burtt Davy* (N. Y. Bot. Gard. Herb.).

Lower California: near Santo Tomas, 12 April, 1886, *Orcutt* (Mo. Bot. Gard. Herb.).

This form differs from *I. Nuttallii* A. Br. chiefly in the smaller plants, both in length and number of leaves, and in the smaller size of the spores. The largest megaspores of *I. Orcuttii* are in the range of the smallest of *I. Nuttallii*. There is also a difference in the peripheral strands in that *I. Nuttallii* usually has three, of which the weakest or dorsal sometimes fails to develop. In *I. Orcuttii*, no such strands appear in the various leaves I have examined, though A. A. Eaton reported the presence of two weak groups of cells, a dorsal and ventral. Brandegee's material from San Diego combines megaspores with prominent markings that plainly fall in the range of *I. Nuttallii* (364–448 μ), sporangia larger than those of *I. Orcuttii*, but leaves the length of the latter (2.5–3 cm.), with no peripheral strands. Since it is believed that the leaf characters are more subject to ecological factors, these are here given less weight, and this specimen is

placed at present with *I. Nuttallii,* rather than with *I. Orcuttii,* with which Eaton placed it.

These two species are very close to each other, and with further evidence *I. Orcuttii* may prove a variety of *I. Nuttallii.*

28. I. humilior A. Br. Linnaea **25**: 722. 1852.

I. Hookeri A. Br. Monatsber. K. Akad. Wiss. Berlin, 538. 1868; Motel. & Vendr. Actes Soc. Linn. Bord. **36**: 340. 1883.

Calamaria humilior Kuntze, Rev. Gen. Pl. **2**: 828. 1891-93.

I. Stuartii A. Br. Monatsber. K. Akad. Wiss. Berlin, 539. 1868; Motel. & Vendr. Actes Soc. Linn. Bord. **36**: 339. 1883.

Corm compressed, 2-lobed; leaves somewhat coarse, rigid, tough, attenuate toward apex, obtuse, with somewhat thick, dark epidermis; stomata lacking; ligule short, cordate triangular; velum complete; sporangium small; megaspores 650–770 μ in diameter, with many small, little elevated, sometimes confluent tubercles on all faces; microspores 30–32 μ long, very short denticulate-muricate.

Distribution: So. River Esk, Tasmania.

The characters on which Braun separated the species *I. Hookeri* from *I. Stuartii* (the two were originally included in the species *I. humilior* by him) hardly seem of more than ecological significance (as softness of leaves) or are within the range of variation in any species (as dark coloring at the base of the leaves). Further he used only one specimen on which to base *I. Stuartii.* It would seem to the writer who has only the description on which to base judgment that the relation between these two is closer than as adjacent species, and they are accordingly united in the original *I. humilior* A. Br.

29. I. melanospora Engelm. Trans. St. Louis Acad. Sci. **3**: 395. 1877, and **4**: 383. 1882; Baker, Jour. Bot. **18**: 69. 1880; Motel. & Vendr. Actes Soc. Linn. Bord. **36**: 359. 1883; Chapman, Fl. Southern U. S., ed. 2, 672. 1889; Small, Fl. Southeastern U. S. 25. 1903.

Calamaria melanospora Kuntze, Rev. Gen. Pl. **2**: 828. 1891-93.

Corm 2-lobed; leaves 5–11, 2.5–7 cm. long, slender, tapering very gradually to apex, almost setaceous, light green, spreading; stomata present; peripheral strands none; ligule small, triangular; sporangium orbicular, 1–2 mm. long, completely covered by

velum; megaspores dark gray when dry, black when wet, 400–480 μ in diameter, with small rough warts sometimes extended into short narrow ridges, which rarely anastomose; commissural ridges thin and blade-like; microspores brown, 26–31 μ long, smoothish to papillose.

Distribution: Stone Mountain, Georgia.

Specimens examined:

Georgia: shallow ponds on the summit of Stone Mt., May, 1869, *Canby* (Mo. Bot. Gard. Herb., Gray Herb., and U. S. Nat. Herb.), TYPE; St. Louis culture from Stone Mt. material, 13 August, 1875, *Engelmann,* (Mo. Bot. Gard. Herb.); top of Stone Mt., April, 1875, *Gray* (Gray Herb.); cultivated by *Engelmann* from young plantlets brought by A. Gray from Stone Mt., 28 September, 1875, *Engelmann* (Mo. Bot. Gard. Herb.); St. Louis culture (from roots brought from Stone Mt. in September, 1876), August, 1877, *Engelmann 1954* (Mo. Bot. Gard. Herb.); shallow depressions on summit of Stone Mt., 13 April, 1897, *ex Biltmore Herb. 4264* (Mo. Bot. Gard. Herb., Gray Herb., and U. S. Nat. Herb.); shallow depressions on summit of Little Stone Mt., 15 May, 1897, *Biltmore Herb. 4264 b* (Univ. Minn. Herb.); Stone Mt., 17 April, 1891, *Underwood* (U. S. Nat. Herb.); "matured in laboratory" (from Stone Mt., 17 April, 1891), August, 1891, *Underwood* (U. S. Nat. Herb.); "grown in laboratory until December, 1891," (from Stone Mt., 17 April, 1891), *Underwood* (U. S. Nat. Herb.); top of Stone Mt., De Kalb Co., 25 July, 1897, *Eggert* (Mo. Bot. Gard. Herb.); "grown from Eggert's plants," 1898, *ex Herb. Eaton* (Mo. Bot. Gard. Herb. and Univ. Minn. Herb.).

30. I. lithophila Pfeiffer, sp. nov.[1]

Corm 2-lobed, small; leaves 6–14 in number, 10–12 cm. long, slender but not filiform, flexuous; stomata numerous; peripheral strands variable, none or 3, weak; ligule very small, cordate triangular; sporangium 2.5–4 mm. long, orbicular to oblong, com-

[1] **I. lithophila** sp. nov. Cormus bilobatus, parvulus. Folia numero 6–14, longitudine 10–12 cm., gracilia, flexilia, stomatibus numerosis instructa, fibris peripheric is destituta vel tribus invalidis instructa. Lingula parvula, cordato-triangulata. Sporangia longitudine 2.5–4 mm, orbiculata vel oblongata, velo completo. Macrosporae diam. 290–360 μ, madidae fuscescentes, siccae cineraceae, leves vel humilibus brevibus aliquantulum extentis jugis leviter ornatae. Microsporae coffeaceofuscae, longitudine 30–33 μ, distincte tuberculatae vel spinulosae.

pletely covered by velum; megaspores 290–360 μ in diameter, with prominent high, rather narrow, commissural ridges; surface of megaspores gray when dry, brown when wet, smooth or faintly marked with low, short or somewhat extended, usually distant ridges; microspores dark brown, chiefly 30–33 μ, high-tuberculate or spiny.

Distribution: Texas.

Specimen examined:

Texas: in shallow depression in granite on east slope of Granite Mt., 70 mi. northwest of Austin, 9 May, 1914, *McAllister* (Mo. Bot. Gard. Herb. and N. Y. Bot. Gard. Herb.), TYPE.

31. I. flaccida Shuttlew. A. Br. Flora **29**: 178. 1846; Am. Jour. **3**: 2. 1847; Chapman, Fl. Southern U. S. 602. 1889; Engelm. Trans. St. Louis Acad. Sci. **4**: 386. 1882.

I. flaccida var. *rigida* Engelm. Trans. St. Louis Acad. Sci. **4**: 386. 1882.

I. flaccida var. *Chapmani* Engelm. Trans. St. Louis Acad. Sci. **4**: 386. 1882.

I. Chapmani Small, Ferns of Florida, 133. 1918.

Calamaria flaccida Kuntze, Rev. Gen. Pl. **2**: 828. 1891-93.

Corm 2-lobed; leaves 8–40, 10–40 cm. long, slender, light green, sharp-pointed, with usually narrow, membranaceous margin; stomata numerous; peripheral strands 4; ligule short-triangular; sporangia oblong, 3–5 mm. long, completely covered by the velum; megaspores light, 300–500 μ in diameter, sometimes less; apical face rarely smooth, usually marked centrally with few large tubercles; basal face with bold, short, rounded ridges, sometimes anastomosing; microspores light brown, 26–33 μ long, slightly papillose.

Distribution: Georgia, Florida.

Specimens examined:

Georgia: in very shallow water or entirely emersed, in wet pine-barrens, Sumter Co., 5 July, 1901, *Harper 1010* (Mo. Bot. Gard. Herb., U. S. Nat. Herb., and Gray Herb.); in sluggish pine-barren stream east of Douglas, Coffee Co., 19 July, 1902, *Harper 1429* (Mo. Bot. Gard. Herb., U. S. Nat. Herb., and Gray Herb.).

Florida: Lake Immonia, north of Tallahassee, 1842-49, *Rugel* (Mo. Bot. Gard. Herb.), TYPE; marshes, Apalachicola, *Chap-*

man? (Mo. Bot. Gard. Herb.); lakelet of clear limestone water near Marianna, August, 1850, *Chapman* (Mo. Bot. Gard. Herb.); marshes, Apalachicola, 1890, *Herb. Chapman* (U. S. Nat. Herb.); Manatee, April, 1878, *Garber without number* (Mo. Bot. Gard. Herb. and U. S. Nat. Herb.); same place and date, *Garber 2312* (Mo. Bot. Gard. Herb. and U. S. Nat. Herb.); same, *Garber 32* (U. S. Nat. Herb., N. Y. Bot. Gard. Herb., and Gray Herb.); open miry places in Turnbull Swamp, Halifax River, May, *Curtiss 3813* (U. S. Nat. Herb.); Lake Flirt, August, 1878, *Garber* (Mo. Bot. Gard. Herb.).

31a. Var. **alata** (Small) Pfeiffer, var. nov.

I. alata Small, Ferns of Florida, 133. 1918.

Similar to the species in stature and leaf characters, but differing in spore markings; upper faces usually crowded with tubercles, which may become ridge-like; lower face with bold rounded ridges so anastomosing as to give more or less irregularly reticulate effect; spore range is about the same, 290–540 μ as extremes, with 430–540 μ most commonly occurring. A form in which the megaspores are usually larger (430–540 μ) and the microspores in the higher range of 30–33 μ, then showing spines quite readily, might be distinguished (*Eaton 832* and *337*, *Curtiss 3813*, Mo. Bot. Gard. Herb.).

Distribution: Georgia, Florida.

Specimens examined:

Georgia: in sluggish pine-barren stream, Bulloch Co., partly emersed, 10 June, 1901, *Harper 843* (U. S. Nat. Herb.); in sluggish pine-barren stream, partly emersed, Bulloch Co., 26 June, 1901, *Harper 951* (Mo. Bot. Gard. Herb., U. S. Nat. Herb., Gray Herb., and N. Y. Bot. Gard. Herb.); in cypress pond near Cobb, Sumter Co., 11 July, 1901, *Harper 1046* (Mo. Bot. Gard. Herb., Gray Herb., U. S. Nat. Herb., and N. Y. Bot. Gard. Herb.).

Florida: open miry places in Turnbull Swamp, Halifax River, May, *Curtiss 3813* (Mo Bot. Gard. Herb.); margin of shaded pond, Riverland, Sumter Co., 23 July, 1900, *Curtiss 6696* (Mo. Bot. Gard. Herb. and N. Y. Bot. Gard. Herb.); Miami River and Everglades, Dade Co., 17 November, 1903, *Eaton*

337 (Mo. Bot. Gard. Herb.); muddy alligator hole at Gossman's, Dade Co., 25 February, 1905, *Eaton 1244* (Mo. Bot. Gard. Herb.); Fort Ogden, De Soto Co., 31 March, 1905, *Eaton 1455* (Mo. Bot. Gard. Herb.); without locality or date, *Eaton 832* (Mo. Bot. Gard. Herb.).

The characteristic on which Small named the species *I. alata,* namely, prominent wings in the lower parts of the leaves, is apt to be found in any large-bulbed form, where the leaf bases become broad. In regard to the spore markings, it is possible to find transitional material (*Harper 1046*).

32. I. Lechleri Mett. Fil. Lechler. 2: 36. 1859; A. Br. Verh. Bot. Ver. Brandenb. 4: 331. 1862; Baker. Jour. Bot. 18: 68. 1880, and Fern Allies, 126. 1887; Motel. & Vendr. Actes Soc. Linn. Bord. 36: 357. *pl. 15. fig. 1–2.* 1883.

Calamaria Lechleri Kuntze, Rev. Gen. Pl. 2: 828. 1891-93.

I. socia A. Br. Verh. Bot. Ver. Brandenb. 4: 332. 1862.

I. Karstenii A. Br. Verh. Bot. Ver. Brandenb. 4: 332. 1862.

Corm 2-lobed; leaves 5–15, 4 cm. long, medium fine, tapering to point, from base widened by membranous sheath; peripheral strands none; stomata fairly numerous; sporangia 3–4 mm. long; velum complete; megaspores white, 380–440 μ in diameter, with roughened surface, marked by very low tuberculate and serpentine elevations; microspores ashy brown, 30–36 μ long, markedly spinulose.

Distribution: Argentina.

Specimen examined:

Argentina: Province of Cordoba, 2 February, 1887, *Hieronymus 774* (U. S. Nat. Herb.).

This specimen is labeled by Hieronymus as *I. socia* A. Br., which is but a form of *I. Lechleri* Mett. according to Braun, who at the same time described *I. Karstenii,* which seems to fit this plant a little better because of spinulose microspores. Braun reduced both species to *I. Lechleri,* widening its range.

33. I. triquetra A. Br. Verh. Bot. Ver. Brandenb. 4: 332. 1862; Motel. & Vendr. Actes Soc. Linn. Bord. 36: 325. 1883.

Calamaria triquetra Kuntze, Rev. Gen. Pl. 2: 828. 1891-93.

I. Andina Spruce in Motel. & Vendr. Actes Soc. Linn. Bord.

36: 325. 1883.

Corm 2-lobed; leaves 6–100, coarse, erect, form abruptly pointed, triangular in cross-section; stomata and peripheral strands lacking; sporangia oblong, truncate, hardly spotted; velum lacking; megaspores inconspicuously tuberculate above, distinctly in center of basal part; microspores smooth, brown or white.

Distribution: South America, Peru.

This description is derived from a combination of characters given by A. Braun and Motelay & Vendryès.

34. I. Howellii Engelm. Trans. St. Louis Acad. Sci. 4: 385. 1882; Underwood, Native Ferns and Fern Allies, 124. 1882; Eaton, Fern Bull. 8: 32–33. 1900; Piper and Beattie, Fl. Wash. 8. 1914.

I. nuda Engelm. Trans. St. Louis Acad. Sci. 4: 385. 1882.

I. Underwoodi Hend. Bot. Gaz. 23: 124. 1897.

I. melanopoda var. *californica* A. A. Eaton in Gilbert, List N. Am. Pterid. 10: 27. 1901.

Corm 2-lobed; leaves 10–30, rarely 50, 5–24 cm. long, bright green, erect or slightly outspread, slender (less so in emersed forms), with wide membranaceous margin extending 1–5 cm. above sporangium level, sometimes abruptly narrowed; stomata numerous; peripheral strands usually 4, sometimes 1 or more lacking; ligule narrow, elongated triangular; sporangia orbicular to oblong, 3–6, rarely 8, mm. long, frequently brown-spotted, partially covered by velum, up to 1/3; megaspores white, 420–520 μ in diameter, more or less obscurely marked with simple tubercles to short crests, isolated or anastomosing, sometimes crowded, sometimes distant; microspores 25–33 μ long, chiefly 27 μ, smoothish to short spinulose.

Distribution: W. Montana, Idaho, Washington, Oregon, California.

Specimens examined:

Montana: 3000 ft. alt., Bigfork, Flathead Co., 14 August, 1909, *Jones* (Mo. Bot. Gard. Herb.); border of Swan Lake, 15 August, 1901, *Umbach* (U. S. Nat. Herb.).

Idaho: in wet places along Paradise Creek, Moscow, 11 June, 1895, *Henderson 2894* (U. S. Nat. Herb.); wet ground about pools, Paradise Creek, Moscow, without date, *Henderson*

(N. Y. Bot. Gard. Herb.); low soil, forks of St. Mary's River, alt. 1000 m., 3 July, 1895, *Leiberg 1149* (U. S. Nat. Herb.); growing in water, pools near Moscow, but maturing macrospores and microspores in mud, 24 June, 1897 and 30 July, 1898, *Henderson* (Gray Herb.); about forest, Nez Perces Co., alt. 3500 ft., 30 July, 1896, *A. A. & E. Gertrude Heller 3482* (Mo. Bot. Gard. Herb., U. S. Nat. Herb., and Univ. Minn. Herb.); in mud, Warrens Meadows, Eastern Latah Co., 2 July, 1898, *Henderson 2978* (Mo. Bot. Gard. Herb.); in water or mud, Moscow, 24 June and 2 August, 1898, *Henderson* (Mo. Bot. Gard. Herb.); Moscow, 30 May, 1897, *Henderson 2894* (Mo. Bot. Gard. Herb.); wet shores, Lake Coeur d'Alene, alt. 650 m., 1 October, 1895, *Leiberg 1656* (U. S. Nat. Herb.); wet shores of Lake Pend d'Oreille, alt. 650 m., 2 October, 1895, *Leiberg 1663* (U. S. Nat. Herb.); lake shore, Sand Point, 24 August, 1901, *Umbach* (U. S. Nat. Herb.).

Washington: near Spangle, Spokane Co., 28 June, 1884, *Suksdorf 2369* (Mo. Bot. Gard. Herb.); in slow shallow stream, Falcon Valley, 30 July, 1885, *Suksdorf 833* (Mo. Bot. Gard. Herb. and U. S. Nat. Herb.); in slow shallow stream, Falcon Valley, 6 September, 1886, *Suksdorf 2370* (Mo. Bot. Gard. Herb.); in mud in shallow water, becoming dry in summer, Spokane Co., 10 June and 11 July, 1889, *Suksdorf 950* (Mo. Bot. Gard. Herb. and U. S. Nat. Herb.); Rock Creek, near Mica Peak, Spokane Co., 5 June, 1889, *Suksdorf 2368* (Mo. Bot. Gard. Herb.); near Rockland, Klickitat Co., 15 April, 1890, *Suksdorf 1235* (Mo. Bot. Gard. Herb.); in a ditch, Falcon Valley, 30 July and 16 October, 1895, *Suksdorf 2372* (Mo. Bot. Gard. Herb.); Falcon Valley, Klickitat Co., 16 July, 1896, *Suksdorf 2613* (Mo. Bot. Gard. Herb.); in shallow water, Falcon Valley, 16 July, 1896, *Suksdorf 2479* (Mo. Bot. Gard. Herb.); Falcon Valley, 28 June, 1898, *Suksdorf 2616* (Mo. Bot. Gard. Herb.); Rockland, Klickitat Co., 10 May, 1899, *Suksdorf 2618* (Mo. Bot. Gard. Herb.); muddy banks of Pend d'Oreille River near Cusick, 21 September, 1903, *Piper 4209* (Mo. Bot. Gard. Herb. and U. S. Nat. Herb.).

Oregon: on the borders of ponds, The Dalles, 1 June and 1 August, 1880, *J. & T. J. Howell* (Mo. Bot. Gard. Herb. and U. S. Nat. Herb.), TYPE; The Dalles, October, 1880, *T. J.*

Howell (Mo. Bot. Gard. Herb. and U. S. Nat. Herb.); The Dalles of the Columbia, 11 October, 1881, *Pringle* (Mo. Bot. Gard. Herb. and U. S. Nat. Herb.); Hood River, May, 1882, *T. J. Howell* (N. Y. Bot. Gard. Herb.); The Dalles, in small ponds, 20 May, 1882, *T. J. Howell* (Mo. Bot. Gard. Herb.); shallow pond 14 miles below The Dalles, 21 May, 1882, *T. J. Howell* (Mo. Bot. Gard. Herb.); nearly submerged in small ponds, Hood River, 22 May, 1882, *T. J. Howell* (Mo. Bot. Gard. Herb. and U. S. Nat. Herb.); Hood River, 3 July, 1891, *T. J. Howell 1521* (Mo. Bot. Gard. Herb., U. S. Nat. Herb., and Univ. Minn. Herb.); in small ponds at The Dalles, May, 1895, *T. J. Howell 698* (Mo. Bot. Gard. Herb.); near Dalles City, 4 May, 1898, *Suksdorf 2617* (Mo. Bot. Gard. Herb.); in or near shallow water near Dalles City, Wasco Co., 7 June, 1904, *Suksdorf 642* (Mo. Bot. Gard. Herb.); shallow water on shore of Rogue River, near Solitude Bar, 26 June, 1917, *Nelson 1531* (Gray Herb.); completely submerged in standing water along S. P. tracks, 3 mi. south of Salem, 27 June, 1921, *Nelson 3939* (Mo. Bot. Gard. Herb.); bottom of dried-up pool, along S. P. tracks, 3 mi. south of Salem, 16 July, 1921, *Nelson 4059* (Mo. Bot. Gard. Herb.).

California: in shallow water, gravel, submerged, growing singly, Bear Valley, San Bernardino Mt., alt. 7000 ft., August, 1882, *S. B. & W. F. Parish 1440* (Mo. Bot. Gard. Herb. and U. S. Nat. Herb.); in dry beds of shallow ponds, Olema, June, 1886, *Curran* (Mo. Bot. Gard. Herb.); Priest Valley, Monterey Co., 13 May, 1893, *Miss Eastwood* (Mo. Bot. Gard. Herb.); El Cajon, April, 1895, *Brandegee* (Mo. Bot. Gard. Herb.); on sand meadow, elev. 9000 ft., south fork Kaweah River, Tulare Co., 1 August, 1895, *Dudley 1043* (Dudley Herb.); in a pond, near Hyampom, Trinity Co., 10 June, 1896, *Howe & Blasdale* (Mo. Bot. Gard. Herb.); growing wholly or partially submerged in pond near Hyampom, Trinity Co., 10 June, 1896, *Howe* (N. Y. Bot. Gard. Herb.); in a marsh about a mile from Olema, Marin Co., 4 July, 1896, *Miss Eastwood* (Mo. Bot. Gard. Herb., Gray Herb., U. S. Nat. Herb., Univ. Minn. Herb.); pools in the plains, Chapman's, Mariposa Co., 27 April, 1897, *Congdon 91* (Gray Herb.); Powder Mill Canyon, Santa Cruz, 25 May, 1900,

Thompson (Mo. Bot. Gard. Herb.); Powder Mill Canyon, Santa Cruz, 9 May, 1901, *Mrs. C. H. Thompson* (Mo. Bot. Gard. Herb. and Univ. Minn. Herb.); in a winter pond hole, elev. 2000 ft., near Burnett Creek, Monterey Co., 4 April, 1901, *Dudley* (Mo. Bot. Gard. Herb.); Woodside Valley pond, San Mateo Co., 31 October, 1909, *Dudley* (Dudley Herb.); common locally in shallow edges of sloughs, Chico, Butte Co., 30 May, 1903, *Copeland 3281* (Mo. Bot. Gard. Herb., Gray Herb., and U. S. Nat. Herb.); Coal Mine Ridge Ponds, Santa Cruz Mountains, 28 May, 1906, *McMurphy* (U. S. Nat. Herb.); edge of pond west of Scofield Pond, Coal Mine Ridge, 26 June, 1908, *Dudley* (Dudley Herb.); Coal Mine Ridge, 26 May, 1910, *Dudley* (Dudley Herb.); Coal Mine Ridge, San Mateo Co., 19 May, 1906, *McMurphy* (Dudley Herb.).

Lower California: Sierra El Taste, November, 1902, *Brandegee* (Mo. Bot. Gard. and U. S. Nat. Herb.).

The material collected by Brandegee at El Cajon, Cal., April, 1895, and at Sierra El Taste in November, 1902, is unusual for *I. Howellii* in the small spore size. The former has characteristic markings, has megaspores 360–400 μ in diameter (26–30 μ for microspores). The latter has megaspores 360–400 μ (26–30 μ for microspores), smoothish to lightly tuberculate, recalling somewhat *I. mexicana* but more nearly resembling *I. Howellii* in habit. Both are placed here provisionally, since the size of plant accords well and is too large for the var. *minima* with which the spore size would place these specimens.

Nelson's numbers 3939 and 4059 represent somewhat aberrant forms in the degree of development of the ridges on the megaspores, and in the long leaves (20–35 cm.), but they seem to fall within the range of *I. Howellii* rather than to be separable as a new form.

34a. Var. **minima** Pfeiffer, comb. nov.

I. minima Eaton, Fern Bull. **6**: 30. 1898.

Corm 2-lobed; leaves 7–16, 3–6 (sometimes 8–10) cm. long, fine, somewhat spreading, attenuate at tip; stomata present; peripheral strands usually 4, weak; ligule triangular, slightly elongated; sporangium 2–3 mm. in length, about 1/3 covered by velum; megaspores white, 320–420 μ in diameter, marked

with vague short crests, tubercles, like species; microspores 23–30 μ, rarely 33 μ, in length, almost smooth to spinulose.

Distribution: Washington, California, Lower California.

Specimens examined:

Washington: in a slow shallow stream, Falcon Valley, 6 September, 1886, *Suksdorf 2371* (Mo. Bot. Gard. Herb.); damp places on prairies near Waverley, Spokane Co., 16 May, 1889, *Suksdorf 2365, 2366* (Mo. Bot. Gard. Herb.); on wet ground near Spangle, Spokane Co., May, 1889, *Suksdorf 2367* (Mo. Bot. Gard. Herb.).

California: San Diego, May, 1903, *Orcutt* (Mo. Bot. Gard. Herb. *not* U. S. Nat. Herb., same date and place).

Lower California: Sierra de la Laguna, 23 January, 1890, *Brandegee 674* (Gray Herb.).

The form differs from the type species in its smaller size, not only in leaf length and thickness, but also in megaspores and microspores.

A. A. Eaton founded his species *I. minima* on a 3-lobed specimen of this form. Since most of the material cited proves to be 2-lobed, it is supposed that the occurrence of 3 lobes is like the chance development reported occasionally in other regularly 2-lobed species.

35. I. Bolanderi Engelm. Am. Nat. 8: 214. 1874; Baker, Jour. Bot. 18: 68. 1880; Motel. & Vendr. Actes Soc. Linn. Bord. 36: 338. 1883; Engelm. in Brewer & Watson, Bot. Cal. 2: 350. 1880; Coulter, Bot. Rocky Mts. 435. 1885; Engelm. Trans. St. Louis Acad. Sci. 4: 381. 1881; Macoun, Cat. Canad. Pl. pt. 4: 293. 1888; Piper, Contr. U. S. Nat. Herb. 9: 89. 1906; Coulter & Nelson, Bot. Rocky Mts. 25. 1909.

Calamaria Bolanderi Kuntze, Rev. Gen. Pl. 2: 828. 1891-93.

I. californica Engelm. in Gray, Manual, ed. 5, 677. 1867.

I. Bolanderi var. *Parryi* Engelm. Am. Nat. 8: 214. 1874.

I. Bolanderi Sonnei Hend. Bull. Torr. Bot. Club 27: 349. 1900.

Corm deeply 2-lobed; leaves 6–25, 6–13 cm. long, rarely 25 cm., slender, tapering to a very fine point, bright green, soft; stomata not numerous; peripheral strands usually lacking; ligule small, cordate; sporangia 3–4 mm. long, about 1/4–1/3 covered by velum; megaspores white, sometimes bluish, 300–440 μ, rarely

480 μ, in diameter, obscurely or more distinctly marked with low tubercles or wrinkles; microspores 23–30 μ long, more or less spinulose.

Distribution: Idaho, Wyoming, Colorado, Utah, Arizona, British Columbia, Washington, Oregon, California.

Specimens examined:

Idaho: Bitter Root Forest Reserve, alt. 2050 m., 26 August, 1897, *Leiberg 39* (Mo. Bot. Gard. Herb.); head of Bear Creek, Bitter Root Forest Reserve, alt. 2050 m., 26 August, 1897, *Leiberg 2939* (U. S. Nat. Herb.).

Wyoming: shallow pond near falls of Yellowstone River, 1873, *Parry 307* (Mo. Bot. Gard. Herb., N. Y. Bot. Gard. Herb., and Gray Herb.); Yellowstone Park, June, September, 1885, *Tweedy 417* (U. S. Nat. Herb.); ponds, Snake River, 9000 ft., August, 1897, *Tweedy 362* (N. Y. Bot. Gard. Herb.); Yellowstone Lake, 12 August, 1897, *Rydberg & E. A. Bessey 3520* (U. S. Nat. Herb., N. Y. Bot. Gard. Herb., and Gray Herb.); Yellowstone Park, 4 August, 1902, *Mearns 2807* (U. S. Nat. Herb.); entirely submerged in shallow pond cut off from north end of Yellowstone Lake, 16 August, 1900, *C. E. Bessey 2* (N. Y. Bot. Gard. Herb.).

Colorado: ponds in Elk Mts., 1881, *Brandegee 2001* (Mo. Bot. Gard. Herb.); lake in Gunnison River Valley, 10,000 ft. alt., lakes near timber line, main range, Routt Co., September, 1891, *Trelease* (Mo. Bot. Gard. Herb.); (probably) submerged on coarse granite bottom, Ward, Boulder Co., alt. 2500 m., *Clokey* (*Schmoll*) *3986* (Mo. Bot. Gard. Herb.).

Utah: subalpine lake, Alta, Wasatch Mts., 12 August, 1879, *Jones* (Mo. Bot. Gard. Herb. and U. S. Nat. Herb.); Alta, Wasatch Mts., August, 1883, *Jones* (N. Y. Bot. Gard. Herb.).

Arizona: in a lake about 2 miles east of Tunnel Road, Black Mesa Forest Reserve, 1 June, 1900, *Coville 1053* (U. S. Nat. Herb.).

British Columbia: Indian Reservation, Kamloops, 29 June, 1889, *John Macoun 14212* (Gray Herb.); in 6 feet of water, Lake Mara, Sicamous, 7 July, 1889, *J. Macoun* (N. Y. Bot. Gard. Herb.).

Washington: ponds, alt. 6300 ft., Cascade Mts., August, 1882, *Tweedy* (Mo. Bot. Gard. Herb. and N. Y. Bot. Gard. Herb.);

lakes of Cascade Mts., October, 1882, *Brandegee* (Mo. Bot. Gard. Herb.); ponds, Mt. Paddo (Adams), August, 31 October, 1881, *Suksdorf* (Mo. Bot. Gard. Herb. and U. S. Nat. Herb.); Mt. Adams, 12 August, 1882, *Thos. Howell* (N. Y. Bot. Gard. Herb.); Mt. Adams, alt. 6000 ft., 21 August, 1886, *Suksdorf 2375* (Mo. Bot. Gard. Herb.).

Oregon: Alpine, eastern Oregon, 1886, *Cusick 1451* (Gray Herb.); Gayhart Buttes, alt. 2250 m., 7 August, 1896, *Coville & Leiberg 271* (U. S. Nat. Herb.); in a pond, Flag Basin, Bear Creek watershed, Wallowa Mts., 9 September, 1907, *Coville 2483* (U. S. Nat. Herb.).

California: small lakes, Cisco, Sierra Nevada, June, 1870, *Bolander* (Mo. Bot. Gard. Herb.); near Mono trail, alt. 10,000 ft., 1866, *Bolander 5093* (Mo. Bot. Gard. Herb. and U. S. Nat. Herb.); Upper Tuolumne River, little pools, alt. 9000–10,000 ft., 1866, *Bolander 5091* (Mo. Bot. Gard. Herb. and U. S. Nat. Herb.); Mt. Dana, alt. 10,000 ft., 1866, *Bolander 5080* (Mo. Bot. Gard. Herb.); Mary's Lake, near summit, alt. 7000 ft., June, 1870, *Bolander* (Mo. Bot. Gard. Herb.); Ice Lake near Soda Spring station, Sierra Nevada, alt. 7500 ft., 11 October, 1880, *Engelmann* (Mo. Bot. Gard. Herb. and U. S. Nat. Herb.); lakes, Summit Valley, alt. 7500 ft., 20–22 September, 1882, *Pringle* (Mo. Bot. Gard. Herb., Gray Herb., and N. Y. Bot. Gard. Herb.); Webber Lake, Sierra Co., *Lemmon* (Mo. Bot. Gard. Herb. and Gray Herb.); Lake Tahoe, May, 1889, *Lemmon* (Mo. Bot. Gard. Herb.); pond about 2 miles southwest of Whitney Meadows, Sierra Nevada, Tulare Co., 26 August, 1891, *Coville & Funston 1722* (N. Y. Bot. Gard. Herb. and U. S. Nat. Herb.); in pool on mountainside northwest of Whitney Meadows, Sierra Nevada, Tulare Co., 20 August, 1891, *Coville & Funston 1643* and *1650* (U. S. Nat. Herb.); same station, *Coville & Funston 1643* (Gray Herb. and N. Y. Bot. Gard. Herb.); about 4 miles northwest of Whitney Meadows, Sierra Nevada, Tulare Co., 25 August, 1891, *Coville & Funston 1691* (U. S. Nat. Herb. and N. Y. Bot. Gard. Herb.); Sierra Nevada, 1883, *Parry* (U. S. Nat. Herb.); Ice Lake (abandoned), Summit, Placer Co., 26 September, without year, *Kellogg* (U. S. Nat. Herb., N. Y. Bot. Gard. Herb., and Mo. Bot. Gard. Herb.); Donner Lake, September, 1887, *Curran* (Mo. Bot.

Gard. Herb. and U. S. Nat. Herb.); below Double Peak, Yosemite National Park, 6 August, 1919, *Clemens 2* (U. S. Nat. Herb.); above Dog Lake, Yosemite National Park, 30 July, 1919, *Clemens 1* (U. S. Nat. Herb.).

The varieties described have been placed with the type, since the characters distinguishing them seem either inconstant or not true morphological differences. Material from Yellowstone Lake, described as *I. Bolanderi* v. *Parryi* Engelm. falls well within the range of the type, except for shorter leaves than most other material. The variety *Sonnei,* distinguished by "shorter, more rigid leaves, apparent absence of stomata, almost orbicular macrosporangium, spotted with small dark spots, and in wide velum which covers from 1/3 to 2/3 of the sporangium," has not been available for study, but every point mentioned is the sort in which one anticipates variation within any Isoetes species. For this reason, in addition to the similarity in locality, Donner Lake, Cal., from which specimens were examined that proved to be *I. Bolanderi,* the variety *Sonnei* is here reduced.

35a. Var. **pygmaea** Clute, Fern Allies, 228, 258. 1905.

I. pygmaea Engelm. Am. Nat. 8: 214. 1874.

Calamaria pygmaea Kuntze, Rev. Gen. Pl. 2: 828. 1891-93.

Corm deeply 2-lobed; leaves few (5–15), 2–2.5 cm. long, stout, tapering but rather abruptly narrowed to the apex, with conspicuous membranous margins developed only to upper level of sporangium; stomata and peripheral strands lacking; ligule small, triangular; sporangium small, orbicular, partly covered by very narrow velum; megaspores white, 360–500 μ in diameter, smoothish or indistinctly marked with short wrinkles and tubercles, low and round in silhouette; microspores 26–30 μ, smooth to slightly papillose.

Distribution: Nevada, Arizona, California.

Specimens examined:

Nevada: floating in Walker Lake, brought down from Mono Pass above, 14 August, 1898, *Congdon 991* (Gray Herb.).

Arizona: Huachuca Mts., So. Arizona, *Lemmon* (Mo. Bot. Gard. Herb.).

California: Mono Pass, eastern declivity of Sierra Nevada, alt. 6000 ft., September, 1866, *Bolander 6025* (Mo. Bot. Gard.

Herb.), TYPE; Mono Pass, in deep water, *Bolander 6383* (U. S. Nat. Herb.).

There are two sheets of material, one with a single specimen, the other with two plants, in Mo. Bot. Gard. Herb., from Engelmann's herbarium. The appearance of the leaves is not at all that of *I. Bolanderi,* since they are very short and taper markedly from a wide margin occurring at the sporangium level, but the spore characters are very similar to *I. Bolanderi.* Additional material from U. S. Nat. Herb. shows the same stout leaves, with almost setaceous tips, and is probably from the same collection as the *type 6025.*

36. I. Tuerckheimii Brause in Urban, Symb. Antillanae **7**: 161. 1912.

Corm 2-lobed; leaves 10–31, 5–10.5 cm. long, slender, gradually tapering to apex, with narrow membranaceous margin extending only to level of top of sporangium; stomata at tip of leaf; peripheral strands none; ligule short-triangular, cordate at base; sporangia globose to oblong, 3–4 mm. long, about 1/3 covered by velum; megaspores 410–500 μ in diameter, smooth or lightly marked with rather distant low warts; microspores 26–32 μ long, smooth.

Distribution: Haiti.

Specimens examined:

Haiti (St. Domingo); near Constanzo in Valle Nuevo, alt. 2200 m., in rock fissures in rivulet, August, 1910, *Türckheim 3531* (Mo. Bot. Gard. Herb., Gray Herb., N. Y. Bot. Gard. Herb., and U. S. Nat. Herb.), TYPE.

Of the available species *I. Tuerckheimii* seems to resemble in spore characters *I. mexicana* Underw. It differs in the lack of peripheral strands and in the very different habitat.

37. I. mexicana Underw. Bot. Gaz. **13**: 93. 1888.

I. Montezumae Eaton, Fern Bull. **5**: 25. 1897.

Corm 2-lobed; leaves 10–30, 7–23, or rarely 30, cm. long, fine, erect, tapering, with membranaceous margin 2–3 times length of the sporangium; stomata numerous; peripheral strands usually 4; ligule triangular, somewhat elongated; sporangia 3–6 or even 8 mm. long, with very narrow velum; megaspores white, 320–

460 μ, rarely larger, in diameter, sharply angular in outline, with faces smooth or marked with large low tubercles; microspores fawn-colored, chiefly 27–39 μ long, mostly spinulose.

Distribution: Chihuahua, Hidalgo, Mexico, Morelos.

Specimens examined:

Mexico: wet places, pine plains, base of Sierra Madre, State of Chihuahua, 6 October, 1887, *Pringle 1447* (U. S. Nat. Herb. and Gray Herb.), TYPE; wet places, base of Sierra Madre, 10 October, 1888, *Pringle 1713* (Mo. Bot. Gard. Herb.); Canales Station, State of Hidalgo, 29 September, 1904, *Pringle 8796* (Mo. Bot. Gard. Herb., Gray Herb., and U. S. Nat. Herb.); wet soil, borders of shallow ponds, plains near Flor de Maria, State of Mexico, 28 August, 1890, *Pringle 3459* (Mo. Bot. Gard. Herb. and U. S. Nat. Herb.); shallow pools, Sierra de las Cruces, alt. 9500 ft., State of Mexico, 24 August, 1904, *Pringle 13261* (U. S. Nat. Herb. and Gray Herb.); shallow water near Cuernavaca, State of Morelos, 22 August, 1897, *Pringle 6660* (Mo. Bot. Gard. Herb., Gray Herb., and U. S. Nat. Herb.); "torrent qui descende de Monte San Miguel, vers Lama de la Huerta," alt. 2200 m., vicinity of Morelia, State Michoacán, 10 November, 1910, *Bro. G. Arsène 3653* (U. S. Nat. Herb.).

The species is variable in habit, ranging to almost terrestrial, from the appearance of herbarium material. The species *I. Montezumae* was based on material collected by Pringle in the states of Mexico and Morelos. The distinctive difference in the herbarium specimens lies in the presence of tiny basal scales in some of this material. Since there is variability in this feature in other forms, as *I. Nuttallii* A. Br., probably in accordance with the amount of moisture present, and since the plants growing in shallow water fail to show such persistent leaf-bases, the character is considered ecological. The species is accordingly reduced.

Pringle's No. 13261 is unusual in showing megaspores as large as 660 μ in diameter, but otherwise agrees with the type. These were collected from the soil, but spores from the sporangia were as large as 520 μ, outside the range shown by any other material available.

38. I. melanopoda Gay & Dur. Bull. Soc. Bot. Fr. **11**: 102. 1864; Engelm. Bot. Gaz. **3**: 1. 1878; Baker, Jour. Bot. **18**: 105. 1880, and Fern Allies, 128. 1887; Motel. & Vendr. Actes Soc. Linn. Bord. **36**: 372. *pl. 14. fig. 1–3.* 1883; A. A. Eaton in Gray, Manual, ed. 7, 61. 1908.

I. melanopoda var. *pallida* Engelm. Trans. St. Louis Acad. Sci. 4: 387. 1882.

Calamaria melanopoda Kuntze, Rev. Gen. Pl. 2: 828. 1891-93.

Corm 2-lobed; leaves 15–60, 15–40 cm. long, slender, erect, firm, bright green, usually black and shining at base, with usually pale membranaceous border, little (2–3 cm.) extended above sporangium level; stomata present; peripheral strands 4 or 6 cardinal, plus as many as 14 accessory groups; ligule subulate triangular; sporangia oblong, 0.5–3 cm. long, marked by numerous brown spots; velum variable, from very narrow to covering 1/2 of sporangium; megaspores 280–440 μ in diameter, marked with low tubercles, frequently confluent into short low wrinkles; microspores frequently ashy-gray, 20–30 μ long, fine spinulose.

Distribution: Illinois, Missouri, Iowa, Oklahoma, and Texas.

Specimens examined:

Illinois: Ringwood, 1863, *Vasey* (Mo. Bot. Gard. Herb. and Gray Herb.); wet meadows, without date, *Hall* (Gray Herb.); shallow border of pond, near Wady Petra, Stark Co., 30 June, 1898, *Chase 86* (Mo. Bot. Gard. Herb.); drying bed of shallow pond near Wady Petra, 26 July, 1898, *Chase 136* (Mo. Bot. Gard. Herb.); Athens, Menard Co., *Hall* (Gray Herb.); Athens, 1861, *Hall* (Gray Herb.); Athens, September, 1861, *Hall* (U. S. Nat. Herb.); ponds, Athens, Menard Co., July, 1863, *Dement* (Mo. Bot. Gard. Herb.); from small pond, in water, 6 inches deep, Athens, Menard Co., 3 June, 1865, *Hall* (Mo. Bot. Gard. Herb.); pond dry for several days, Athens, 13 June, 1865, *Hall* (Gray Herb.); Athens, 27 June, 1865, *Hall* (Mo. Bot. Gard. Herb. and Gray Herb.); "wet prairies, shallow ponds, now dry, in spring under water," 19 June, 1865, Athens, *Hall* (Mo. Bot. Gard. Herb. and U. S. Nat. Herb.); Athens, 30 October, 1865, *Hall* (Mo. Bot. Gard. Herb.); Athens, second crop, in water, 3 November, 1865, *Hall* (Gray Herb.); Athens, 25 November, 1865, *Hall* (Mo. Bot. Gard. Herb.); "second crop," Athens, 18 November, 1865, *Hall* (Mo. Bot. Gard. Herb.); Athens, 1

June and October, 1866, *Hall* (Mo. Bot. Gard. Herb.); Fulton Co., 1874, *Wolf* (Gray Herb.); "cultures in Jardin botanique de Bordeaux" sent from Athens by *Hall*, 2 August, 1876, *ex Herb. Motelay* (Mo. Bot. Gard. Herb.); Athens, 23 June, 1878, *Hall* (Mo. Bot. Gard. Herb.); Athens, 8 July, 1878, *Hall* (Mo. Bot. Gard. Herb.); Bluffs Lake, St. Clair Co., June, 1881, *Eggert* (Mo. Bot. Gard. Herb., U. S. Nat. Herb., and Univ. Minn. Herb.); Bluffs Lake, St. Clair Co., 15 June, 1882, *Eggert* (Mo. Bot. Gard. Herb. and Univ. Minn. Herb.); Bluffs Lake, St. Clair Co., 22 June, 1882, *Eggert* (Mo. Bot. Gard. Herb.); "banks of a pond, East St. Louis," St. Clair Co., 9 August, 1882, *Eggert* (Mo. Bot. Gard. Herb.); "Illinois, August," *Mrs. J. M. Milligan* (U. S. Nat. Herb.).

Iowa: Clinton, 1863, *Vasey* (Mo. Bot. Gard. Herb. and Gray Herb.).

Missouri: wet prairies, Little Blue River near Courtney, Jackson Co., 6 July, 1893, *Bush* (Mo. Bot. Gard. Herb.); Jackson Co., wet dogwood flats, uncommon, 6 July, 1893, *Bush 441* (Gray Herb.); Little Blue, Jackson Co., 24 May, 1896, "uncommon," *Bush 746* (Mo. Bot. Gard. Herb.); along, and in, ditches near Little Blue, east of Independence, "very local and rare," 24 May, 1896, *Bush* (Mo. Bot. Gard. Herb.); uncommon on low prairie, Dodson, Jackson Co., 2 May, 1897, *Bush 267* (Mo. Bot. Gard. Herb. and Univ. Minn. Herb.); common in swale, Dodson, 28 June, 1898, *Bush 35* (Mo. Bot. Gard. Herb., Gray Herb., and U. S. Nat. Herb.); common on limestone ledges, Eagle Rock, Barry Co., 3 June, 1897, *Bush 107* (Mo. Bot. Gard. Herb.); Lake City, Jackson Co., *Mackenzie* (Univ. Wyoming Herb.); right bank of St. Francois River, below mouth of Stout Creek, Madison Co., 25 May, 1918, *Greenman 3861* (Mo. Bot. Gard. Herb.); springy bank of St. Francois River, near entrance of Stout Creek, 25 May, 1918, *Pfeiffer 21* (Mo. Bot. Gard. Herb.).

Oklahoma: "overflowed places," Limestone Gap, early June, 1875, *Butler* (Mo. Bot. Gard. Herb.); low wet places in alkali flats, Limestone Gap, 26 May, 1877, *Butler* (Mo. Bot. Gard. Herb.); pools, Limestone Gap, 14 June, 1877, *Butler* (Mo. Bot. Gard. Herb.); "alluvial deep shade in the bed of a dried-up stream," Limestone Gap, 16 June, 1877, *Butler*

(Mo. Bot. Gard. Herb.); pools 1½ mi. north of Limestone Gap, 8 July, 1877, *Butler* (Mo. Bot. Gard. Herb. and U. S. Nat. Herb.); pool by the railroad, Limestone Gap, 10 July, 1877, *Butler* (Mo. Bot. Gard. Herb. and U. S. Nat. Herb.).

Texas: wet pine-woods, Houston, 20 April, 1872, *Hall 859* (Mo. Bot. Gard. Herb., Gray Herb., and N. Y. Bot. Gard. Herb.); Houston, May, 1872, *Hall* (Gray Herb.); swampy grounds, Dallas, June, 1877, *Reverchon 1177* (U. S. Nat. Herb.); wet sands, Dallas, July, 1880, *Reverchon 1177* (Mo. Bot. Gard. Herb. and U. S. Nat. Herb.); mud, bogs, Buzzards' Spring near Dallas, June, 1877, *Reverchon 795* (Gray Herb.); Buzzards' Spring, 1879, *Reverchon* (Mo. Bot. Gard. Herb.); dried pond, Sabine River Bottoms, near Mineola, Wood Co., 2 June, 1903, *Reverchon 3551* (Mo. Bot. Gard. Herb.); shallow ponds, Pine's Island, Angelina Co., 5 May, 1903, *Reverchon 3549* (Mo. Bot. Gard. Herb., Gray Herb., and U. S. Nat. Herb.); Harrisburg, 9 May, 1876, *Joor* (Mo. Bot. Gard. Herb.); rare in pond, Columbia, 17 October, 1900, *Bush 1531* (Mo. Bot. Gard. Herb.); Hockley, 1891, *Thurow 15* (U. S. Nat. Herb.).

Although the early material of *I. melanopoda* appeared quite uniform and therefore the species seemed distinctive, more recent collections tend to add divergent forms. Engelmann early described a variety *pallida,* which he based on "larger plants lacking the black leaf bases of the type, with broader velum and megaspores in the restricted range of 300–350 μ, instead of the 250–400 μ range given for the type." This was based on Texas collections which upon examination show a wide difference in spore sizes, running as high as 440 μ. These specimens do not exceed northern forms in leaf number nor in leaf length. Moreover, it frequently happens that pale-based individuals are found in any stand of *I. melanopoda,* even though there be a preponderance of dark-based forms. It seems proper, therefore, to consider *pallida* as a form rather than as a variety of *I. melanopoda,* occurring singly or in stands.

There is, moreover, intergrading between two species, in the case of *I. melanopoda* and *I. Butleri,* so that some intermediate forms are difficult to place accurately. As an illustration, the examples originally described as *I. Butleri* var. *immaculata* combine in remarkable fashion the fine leaf habit of *I. Butleri* with

the greater length of *melanopoda* and frequently the stronger bulb development of the latter. The range in spore size is intermediate, overlapping the larger of *I. melanopoda* and the smaller of *I. Butleri.*

Much of the material representing this form has been collected in early spring. It is a question whether the fineness of leaves is related to the early development, as the lack of pigment seems to be. Certain it is that some stations have yielded only material labeled *"Butleri immaculata"* in May, and only *"melanopoda"* in June and July. Whether *I. Butleri* as found in Oklahoma (Indian Territory) by Butler, owed its characteristic size and fineness to the alkali flats in which it developed, is another ecological point worth determining. The series from *I. melanopoda* developing in moisture through so-called *pallida,* in drier surroundings, to *I. Butleri,* conceivably might be related to the environment. Pending further evidence in regard to relation, material showing the characteristic habit of *I. Butleri* is placed with that species, though most of it occurring outside of Oklahoma shows the combination of characters which connect it quite definitely also with *I. melanopoda.*

39. I. Butleri Engelm. Bot. Gaz. **3**: 1. 1878; Baker, Jour. Bot. **18**: 105. 1880; Motel. & Vendr. Actes Soc. Linn. Bord. **36**: 360. 1883; Engelm. Trans. St. Louis Acad. Sci. 4: 388. 1882; A. A. Eaton in Gray, Manual, ed. 7, 61. 1908.

I. Butleri var. *immaculata* Engelm. Trans. St. Louis Acad. Sci. 4: 388. 1882.

Calamaria Butleri Kuntze, Rev. Gen. Pl. 2: 828. 1891-93.

Corm 2-lobed; leaves 8–30, 8–15 cm. long, more slender and rigid than *I. melanopoda,* tapering to apex; stomata numerous; peripheral strands usually 4, sometimes more in number; ligule elongated, cordate at base; sporangium oblong, 6–7 mm. long, marked with brown lines; velum very narrow; megaspores variable, commonly 480–650 μ in diameter, sometimes only 360 μ, marked with numerous tubercles, usually distinct, occasionally confluent; microspores 27–37 μ long, papillose.

Distribution: Tennessee, Missouri, Arkansas, Kansas, and Oklahoma.

Specimens examined:

Tennessee: Cedar Glades, Lavergne, May, *Gattinger* (N. Y. Bot.

Gard. Herb.); springy places in cedar barrens, near Lavergne, Rutherford Co., 7 and 17 May, 1880, *Gattinger 3812* (Mo. Bot. Gard. Herb., N. Y. Bot. Gard. Herb., and U. S. Nat. Herb.); cedar barrens at Lavergne, 17 May, 1880, *Gattinger* (Gray Herb.); springy places in limestone flats near Nashville, April, 1886, *Gattinger* (Gray Herb.).

Missouri: common on limestone ledges, Eagle Rock, 3 June, 1897, *Bush 107* (Mo. Bot. Gard. Herb., U. S. Nat. Herb., and Univ. Minn. Herb.); common in barrens, Eagle Rock, 22 May, 1898, *Bush 231* (Gray Herb. and N. Y. Bot. Gard. Herb.); common in barrens, Forsyth, 10 June, 1899, *Bush 68* (Mo. Bot. Gard. Herb., Gray Herb., U. S. Nat. Herb., and N. Y. Bot. Gard. Herb.); rocky barrens, Noel, 11 May, 1915, *Bush 7547* (Mo. Bot. Gard. Herb., N. Y. Bot. Gard. Herb., and Gray Herb.); wet barrens, Swan, 19 May, 1905, *Bush 2917* (Mo. Bot. Gard. Herb. and N. Y. Bot. Gard. Herb.); wet barrens, Swan, 17 May, 1907, *Bush 4511* (Mo. Bot. Gard. Herb., Gray Herb., and N. Y. Bot. Gard. Herb.); rocky hillsides, Jefferson Co., 26 May, 1891, *Eggert* (Mo. Bot. Gard. Herb., Gray Herb., U. S. Nat. Herb., and Univ. Minn. Herb.); rocky hillside, De Soto, Jefferson Co., 29 May, 1891, *Eggert* (Mo. Bot. Gard. Herb. and N. Y. Bot. Gard. Herb.); rocky hillside, De Soto, Jefferson Co., 11 and 25 May, 1896, *Eggert* (Mo. Bot. Gard. Herb. and Univ. Minn. Herb.); De Soto, Jefferson Co., without date, *Eggert* (N. Y. Bot. Gard. Herb.); thin black soil on seeping ledges, limestone barrens 4 mi. northwest of Carthage, Jasper Co., 21 April, 1922, *Palmer 20848* (Mo. Bot. Gard. Herb.); moist depressions in limestone barrens, near Webb City, Jasper Co., 29 May, 1922, *Palmer 21555* (Mo. Bot. Gard. Herb.).

Arkansas: common in barrens, 8 May, 1902, *Bush 1530* (Mo. Bot. Gard. Herb., N. Y. Bot. Gard. Herb., and U. S. Nat. Herb.); wet barrens near Eureka Springs, 8 May, 1902, *Canby 136* (Gray Herb.).

Kansas: rocky soil, Cherokee Co., May, 1897, *Hitchcock 1068* (Mo. Bot. Gard. Herb., U. S. Nat. Herb., Gray Herb., and N. Y. Bot. Gard. Herb.).

Oklahoma: common on alkali flats, Limestone Gap, Atoka Co., first week in June, 1875, *Butler* (Mo. Bot. Gard. Herb.); alkali flats near Limestone Gap, 26 and 28 May, 1877, *Butler*

(Mo. Bot. Gard. Herb.); flats near Limestone Gap, 13 and 16 June, 1877, *Butler* (Mo. Bot. Gard. Herb. and U. S. Nat. Herb.); Limestone Gap, 16 June, 1887, *Butler 24* (N. Y. Bot. Gard. Herb.).

Sect. 2. Echinatae

§ 2. Echinatae. Forms with 2-lobed corms; producing megaspores with distinct spines; microspores smooth or rough; peripheral strands lacking; never terrestrial.

Key to Species

A. Stomata absent.
  a. Velum narrow, covering less than ⅓ of sporangium ---------- *40. I. echinospora*
  b. Velum wide, covering ⅔–¾ of sporangium ---------- *40a. I. echinospora* var. *asiatica*

B. Stomata present.
  a. Megaspores with sharp spines.
    α. Smaller forms, leaves 3–6 cm. in length ---------- *41. I. Brochoni*
    β. Larger forms, leaves chiefly 8 cm. or more in length ---------- *42. I. Braunii*
  b. Megaspores with blunt spines.
    α. Leaves few, 7–15, slender ---------- *42a. I. Braunii* var. *maritima*
    β. Leaves more numerous, 20–40, stout ---------- *43. I. truncata*

40. I. echinospora Dur. Bull. Soc. Bot. Fr. 8: 164. 1861; A. Br. Verh. Bot. Ver. Brandenb. 4: 297. 1862; Babington, Jour. Bot. 1: 1–5. 1863; Milde, Fil. Eur. 279. 1867; Baker, Jour. Bot. 18: 67. 1880, and Fern Allies, 125. 1887; Motel. & Vendr. Actes Soc. Linn. Bord. 36: 334. *pl. 9.* 1883; Engelm. Trans. St. Louis Acad. Sci. 4: 379. 1882.

Calamaria echinospora Kuntze, Rev. Gen. Pl. 2: 828. 1891-93.

Corm 2-lobed; leaves 10–40, 5–12 cm. long, pale green, stout at base, tapering to apex, spreading, recurved, with rather wide membranaceous margins at base; stomata none; peripheral strands none; ligule deltoid, rather wide at base; sporangia globose or oval, 3–7 mm. long, with very narrow velum; megaspores white, 440–540 μ in diameter, densely echinate with fine truncate spines, sometimes toothed; commissural ridges irregular in outline; microspores 23–35 μ in length, rarely 40 μ, sometimes marked with slight reticulations.

Distribution: British Isles, northern and central Europe.

Specimens examined:

British Isles: Wales, "In Cambriae lacu Llyn Padark," with *I. lacustris,* 30 September, 1862, *Gay* (Gray Herb.).

Belgium: Genck-Limbourg, 31 July, 1865, *ex herb. Thielens* (N. Y. Bot. Gard. Herb.); "Belgium," *Le Roy* (N. Y. Bot. Gard. Herb.); Etang à Genck, prov. Limbourg, August, 1862, *Van den Born* (Mo. Bot. Gard. Herb.).

France: Lac de Guery, Puy-de-Dome, 24 August, 1861, *Durieu* (Mo. Bot. Gard. Herb.), TYPE; Lac de Guery, Puy-de-Dome, 21 September, 1881, *Heribaud* (N. Y. Bot. Gard. Herb.); Lac de Guery, August, 1890, *Hy* (Mo. Bot. Gard. Herb.); Lac St. Andéol, Mt. Aubrac, 23 August, 1861, *Gay* (Mo. Bot. Gard. Herb. and Gray Herb.); in Longemer, near Colmar, Vosges, 26 July, 1865, *Schlickum* (N. Y. Bot. Gard. Herb.); Gerardmer (Vosges), August, 1867, *Martin* (Mo. Bot. Gard. Herb. and U. S. Nat. Herb.); Lac de Longemer, Vosges, September, 1874, *Stahl* (Mo. Bot. Gard. Herb.); Lac de Guery, August, 1890, *Cosson* (Gray Herb.).

Italy: Lago d'Orta near Busca, Prov. of Novara, 15 September, 1896, *Chiovenda* (Mo. Bot. Gard. Herb.); Lago d'Orta, August, 1856, *Franzoni* (Mo. Bot. Gard. Herb.); borders of "lacus Cusii" (lago d'Orta—Ital. bor.), 1857, *Cesati* (Mo. Bot. Gard. Herb.).

Norway and Sweden: in lakes of Norway, *Blytt 1951* (Mo. Bot. Gard. Herb.); Krigsbergs, Ivarinsbruk, 17 August, 1866, *Duscu* (U. S. Nat. Herb.); Nerêc Gotlunda, 1864, *Blomberg* (N. Y. Bot. Gard. Herb.); Nyland, Strömfors, 20 July, 1875, *Arrhenius* (N. Y. Bot. Gard. Herb.); near Stockholm, *Anderssen* (Mo. Bot. Gard. Herb.); Vg. Fröjered, August, 1880, *Junger* (N. Y. Bot. Gard. Herb.).

Germany: Feldsee, August, 1846, *Braun* (Mo. Bot. Gard. Herb.); Titisee, Schwarzwald, August, 1864, *Reess* (Mo. Bot. Gard. Herb. and N. Y. Bot. Gard. Herb.); Titisee near Freiburg, August, 1864, *Solms & Reess* (Mo. Bot. Gard. Herb.); Titisee, October, 1863, *de Bary* (Mo. Bot. Gard. Herb.); Feldsee, Schwarzwald, September, 1861, *Thiry* (Mo. Bot. Gard. Herb. and Gray Herb.); Feldsee in Schwarzwald, 1861, *ex. Mus. bot. Berol.* (U. S. Nat. Herb., 594573); Titisee, August, 1864, *Thiry* (Gray Herb.); Schluchsee (royal forest of Baden), 1864, *Braun* (Gray Herb.); Feldsee, 1884, *Christ* (N. Y. Bot. Gard. Herb.); in Feldsee, Schwarzwald, 4

August, 1881, *Study* (N. Y. Bot. Gard. Herb.); sandy shores at upper end of the Schluchsee, October, 1861, *Schildknecht & Thiry 799* (N. Y. Bot. Gard. Herb.); Titisee, September, 1868, *Zickendrath* (N. Y. Bot. Gard. Herb.).

Russia: in Livonia, distr. Riga, "in lacu Bule-See", 10 September, 1901, *Kupffer 14912* (U. S. Nat. Herb.).

40a. Var. **asiatica** Makino, Tokyo Bot. Mag. **18**: 129. 1904.

Differs from the type in having a broad velum, covering 2/3 to 3/4 of the sporangium, in bearing coarser spinules on the megaspores, and in the smoothness of the microspores. The author suggests that it is lacking in stomata by saying that it differs from *I. Braunii* which has stomata and a spotted sporangium.

Distribution: rare. Lake Nojiri, Prov. Shinano.

Description from Makino.

41. I. Brochoni Motel. & Vendr. Actes Soc. Linn. Bord. **45**: 45. *pl. 2.* 1893.

Corm 2-lobed; leaves 8–16, rarely more, 3–6 cm. long, fine, tapering, rosy below, green above, with short, wide membranaceous margin at base; stomata present but not common; peripheral strands none; ligule very short and broad; sporangium globose, 2½–4 mm. long, partially (1/4–1/3) covered by velum; megaspores white, 450–525 μ in diameter, much flattened in outline, marked with very echinate, sharply toothed prominences; microspores 33–53 μ in length, often nearly as wide.

Distribution: France.

Specimens examined:

France: Lac de Naguilles (1854 m. alt.), Ariege, *Motelay* (Mo. Bot. Gard. Herb.), TYPE; Lac de Naguilles, August, 1891, *Hy* (Mo. Bot. Gard. Herb.).

42. I. Braunii Dur. Bull. Soc. Bot. Fr. **11**: 101. 1864.

I. echinospora var. *Braunii* Engelm. in Gray, Manual, ed. 5, 676. 1867.

I. echinospora var. *Boottii* Engelm. in Gray, Manual, ed. 5, 676. 1867.

I. echinospora var. *muricata* Engelm. in Gray, Manual, ed. 5, 676. 1867.

I. echinospora Braunii f. *Boottii* Clute, Fern Allies, 221, 258. 1905.

I. echinospora Brittoni Cockerell, Muhlenbergia **3**: 9. 1907.

I. muricata Dur. Bull. Soc. Bot. Fr. **11**: 101. 1864.

I. ambigua A. Br. in Engelm. Trans. St. Louis Acad. Sci. **4**: 380. 1882.

Corm 2-lobed; leaves usually 10–35, in robust forms 27–55, 8–25 cm. long, or rarely longer, straight or recurved, firm, tapering to apex, with rather wide base with membranaceous borders; stomata present, usually few; peripheral strands none; ligule deltoid; sporangia oblong, spotted, 4–7 mm. long, with velum ½ to completely covering it (western forms of U. S. have narrow velum); megaspores white, 420–580 μ in diameter, marked with numerous spines ranging from single slender spines to those toothed or even confluent in short ridges; microspores fawn-colored, 23–33 μ long, smooth to slightly roughened on surface.

Distribution: North America.

Specimens examined:

Greenland: 60°–60° 43′ N. lat., Southern Greenland ("Tessermint"), probably about 1825, *Jens Vahl* (Mo. Bot. Gard. Herb.); Kingua Neriak, 61° 35′, July, 1889, *Hartz* (Gray Herb.).

Newfoundland: immersed, sandy soil, Channel, 27 July–1 August, 1901, *Howe & Lang 954* (Gray Herb. and N. Y. Bot. Gard. Herb.); small ponds among Siberian Hills back of Birchy Cove (Curling), region of Humber Arm, Bay of Islands, 11 August, 1910, *Fernald & Wiegand 2402* (Gray Herb.); barrens at base of the serpentine table-lands, Bonne Bay, 27 August, 1910, *Fernald & Wiegand 2405* (Gray Herb.); gravelly brook in bog, Bishop Falls, 29 July, 1911, *Fernald & Wiegand 4411* (Gray Herb.); shallow pools in bog, Bishop Falls, Valley of Exploits River, 29 July, 1911, *Fernald & Wiegand 4406* (Mo. Bot. Gard. Herb. and Gray Herb.); shallow pools in the tundra near Quarry (Laurentian Area at head of Exploits River System), 23 August, 1911, *Fernald & Wiegand 4401* (Gray Herb.); deep water near center of middle Birchy Pond (eastern drainage area of Humber River System), *Fernald & Wiegand 2400* (Gray Herb.); wet

sandy shore of Rushy Pond (Valley of Exploits River), 11 August, 1911, *Fernald & Wiegand 4410* (Gray Herb.); muddy pool, Killigrew's (shores of Conception Bay, Avalon Peninsula), 3 August, 1911, *Fernald & Wiegand 4405* (Gray Herb.); diorite tableland, alt. about 550 m., n. region of the Blomidon ("Blow-Me-Down") Mts., 22 August, 1910, *Fernald & Wiegand 2401* (Gray Herb.); Eastern Avalon Peninsula, bog pond on hill south of St. Johns, 2 August, 1911, *Fernald & Wiegand 4407* (Gray Herb. and U. S. Nat. Herb.); Kitty's Brook, eastern waters of the Humber River System, 25 August, 1911, *Fernald & Wiegand 4403* (Gray Herb.); shallow pools on serpentine tableland, alt. about 550 m., northeast region of the Blomidon Mts., w. Newfoundland, 21 August, 1910, *Fernald & Wiegand 2403* (Gray Herb.).

Quebec: Grand Valley, Gaspé, 3 August, 1882, *John Macoun 14220* (Gray Herb.); Madeline River, Gaspé, 5 August, 1882, *John Macoun 14226* (Gray Herb.); lake near Point Fame, Gaspé, 5 August, 1882, *John Macoun 14224* (Gray Herb.); Beau Lac, 14 August, 1902, *Eggleston 3026* (Gray Herb., N. Y. Bot. Gard. Herb., and Dudley Herb.); alpine lakes, 900–1000 m., Table-top Mt., Gaspé, 4 August, 1906, *Fernald & Collins 311* (Mo. Bot. Gard. Herb.); Lac Fortin, Table-top Mt., Gaspé, 10 August, 1906, *Fernald & Collins 320* (Gray Herb.); in muck over granite, Lac 33, Table-top Mt., Gaspé, 4 August, 1906, *Fernald & Collins 316* (Gray Herb.); Lac des Americains, 675 m., western-base Table-top Mt., Gaspé, 1 and 2 August, 1906, *Fernald & Collins 154* (Mo. Bot. Gard. Herb., N. Y. Bot. Gard. Herb., U. S. Nat. Herb., Gray Herb., and Univ. Minn. Herb.); Granite Block Pond, alt. 900–1000 m., Table-top Mt., 7 August, 1906, *Fernald & Collins 318* (Mo. Bot. Gard. Herb. and Gray Herb.); Sargent's Bay, Lake Memphremagog, 3 August, 1903, *Churchill* (Mo. Bot. Gard. Herb.); Mt. Elephantis Landing, Lake Memphremagog, 14 August, 1903, *Churchill* (Mo. Bot. Gard. Herb. and Gray Herb.); pool (tidal?) at mouth of river, Romaine, Lagorgendière, Saguenay, 8 July, 1915, *St. John 90061* (Gray Herb.); growing at least 5 ft. below surface of water, Lake Pratt, near Rivière du Loup, July, 1913, *Bro. Victorin 61* (Gray Herb.); sub-

merged, Lake MacGregor, 3 August, 1917, *Bro. Rolland 6284* (N. Y. Bot. Gard. Herb.); Kirck's Ferry, 16 August, 1916, *Bro. Rolland 65* (Mo. Bot. Gard. Herb.); Richelieu River, Isle Allo-None, 13 August, 1918, *Bro. Victorin* (N. Y. Bot. Gard. Herb.); Lake Pratt Co., Temiscouata, August, 1914, *Bro. Victorin 694* (Mo. Bot. Gard. Herb., U. S. Nat. Herb., and Gray Herb.); in 1 ft. water in sandy-bottomed pond, Petit Rivière Coxipi, Brouage, Saguenay Co., 23 July, 1915, *St. John 90059* (Gray Herb.); shallow pool in tundra, Anse Portage, Archipel de St. Augustin, Saguenay Co., 5 August, 1915, *St. John 90060* (Gray Herb.); 1 ft. of water, hillside pond, Baie des Moutons, Boishébert, Saguenay Co., 15 August, 1915, *St. John 90058* (Gray Herb.).

New Brunswick: Lily Lake, St. Johns, 8 August, 1873, *Boott* (Gray Herb.); St. George, Charlotte Co., 17 August, 1883, *Vroom* (Gray Herb.); muddy pool on shores of St. John River, Connors, Madawaska, 13 July, 1903, *Pease 2249* (Gray Herb.).

Nova Scotia: Shelburn, August, 1873, *James* (Mo. Bot. Gard. Herb.); South Ingonish, 8 August, 1898, *Macoun* (Mo. Bot. Gard. Herb.); Boylston, August, 1890, *Hamilton 81051* in part (Gray Herb.); N. E. Margaree, Cape Breton Isl., 11 August, 1906, *Robinson 335* (N. Y. Bot. Gard. Herb.); (probably) margin of Taylor's Lake, Sunny Brae, Pictou Co., 30 July, 1913, *St. John 1370* (Gray Herb.); muddy lagoon, Charcoal, Valley of the East River, Pictou Co., 2 August, 1913, *St. John 1371* (Gray Herb.); muddy and rocky bottom of a quiet brook, New Tusket, 9 August, 1921, *Fernald & Long 23113* (Mo. Bot. Gard. Herb.).

Maine:

Aroostook Co.: sandy bottom of Beau Lac, 14 August, 1902, *Fernald* (Mo. Bot. Gard. Herb.); Beau Lac, 14 August, 1902, *Eggleston 3026* (U. S. Nat. Herb.); ledgy margin of river, St. Francis, 19 August, 1893, *Fernald 220* (Mo. Bot. Gard. Herb., Gray Herb., N. Y. Bot. Gard. Herb., U. S. Nat. Herb., and Univ. Minn. Herb.); sandy bed of Pettiquaggimas (Glazier) Lake, 8 August, 1893, *Fernald 218* (Mo. Bot. Gard. Herb.); gravelly margin of River St. Francis, 21 August, 1893, *Fernald 219* (Mo. Bot. Gard. Herb., Gray Herb., U. S. Nat. Herb., and Univ. Minn. Herb.); logan by

the river, Fort Kent, 11 August, 1901, *Fernald* (Gray Herb.); logan in St. Johns River, Fort Kent, 11 August, 1901, *Williams 1* (Gray Herb.); bed of Dyer Brook, Island Falls, 28 August, 1897, *Fernald* (Gray Herb.); rapids of St. Croix Stream, Masarde's, 8 September, 1897, *Fernald* (Gray Herb.); river margin, Madawaska, 28 July, 1893, *Fernald* (Gray Herb.).

Penobscot Co.: Pushaw Pond, August, 1899, *F. L. Harvey 2* (Mo. Bot. Gard. Herb.); ledgy margin of Stillwater River, Orono, 4 September, 1893, *Fernald y & g* (Gray Herb. and N. Y. Bot. Gard. Herb.); Chemo Stream, Bradley, 10 August, 1898, *F. L. Harvey* (Mo. Bot. Gard. Herb.); submerged, growing in rock crevices, Chemo Stream, Bradley, 15 July, 1898, *F. L. Harvey* (N. Y. Bot. Gard. Herb.); Chemo Pond, August, 1897, *Merrill* (U. S. Nat. Herb.); same, September, 1897 (Gray Herb.); Chemo Stream, Bradley, September, 1897, *Merrill 10* (N. Y. Bot. Gard. Herb.); tidal mud flats at mouth of Souadabscook Stream, Hampden, 11 September, 1916, *Fernald & Long 12341* (Gray Herb. and Mo. Bot. Gard. Herb.); river margin, Mattawamkeag, 14 September, 1898, *Fernald 2819* (Gray Herb.); muddy river margin, Orono, 1 September, 1893, *Fernald x* (Gray Herb.); tidal mud flats at the mouth of Reed Brook, Hampden, 8 September, 1916, *Fernald & Long 12340* (Gray Herb. and Mo. Bot. Gard. Herb.); mud in crevices of slate, immersed at margin of Mud Pond, Oldtown, 29 August, 1908, *Fernald* (Gray Herb.).

Washington Co.: margin of Lambert Lake, 1 September, 1908, *Plantae Exsiccatae Grayanae, Fernald* (Mo. Bot. Gard. Herb.); granitic gravel and silt at margin of Lambert Lake, 1 September, 1908, *Fernald 105* (Gray Herb. and Dudley Herb.); sandy margin of Pennamaquan River, Pembroke, 18 August, 1909, *Fernald 1215* (Gray Herb.); muddy bed of brook, Cutter, 29 August, 1902, *Fernald* (Gray Herb.).

Hancock Co.: Mt. Desert Isl., Long Pond meadows, Jordan's Stream, 26 August, 1891, *Rand* (N. Y. Bot. Gard. Herb.); bog hole, Long Pond Meadows, 20 September, 1898, *Rand* (Gray Herb.); "Mt. Desert Isl.," *Rand* (Mo. Bot. Gard. Herb.); in clay mud, beach, southeast end of Great Pond, 19 September, 1898, *Rand* (Gray Herb.); stream, meadow

north of Long Pond, Seal Harbor, 21 August, 1889, *Rand* (Gray Herb.); brook, Long Pond Meadows, Seal Harbor, 21 August, 1889, *Redfield 2530* (Mo. Bot. Gard. Herb. and Gray Herb.); muddy pond, Long Pond meadows, 9 September, 1899, *Rand* (Gray Herb.).

Piscataquis Co.: Milo, 2 September, 1897, *Fernald* (Mo. Bot. Gard. Herb. and Gray Herb.); Mt. Katahdin, September, 1898, *Merrill 1408* (U. S. Nat. Herb.); mostly submerged, Three Ponds, Mt. Katahdin, alt. 1500–1800 ft., September, 1898, *Merrill* (N. Y. Bot. Gard. Herb.); Mt. Katahdin, 15–30 August, 1902, *Cowles & Harvey 2* (Mo. Bot. Gard. Herb.); muddy river bottom, Dover, 27 August, 1894, *Fernald* (Gray Herb.); gravelly margin of river, Dover, 3 September, 1894, *Fernald* (Gray Herb.); submerged margin of Pleasant River, Brownville, 3 August, 1904, *Parlin 1753* (Gray Herb.).

Somerset Co.: Lake George, Skowhegan, 30 June and 2 July, 1903, *Eaton* (Mo. Bot. Gard. Herb.); Dead River, 15 August, 1896, *Eaton* (Mo. Bot. Gard. Herb.); quiet pool in river, Dead River, 15 August, 1896, *Fernald* (Gray Herb.).

Waldo Co.: deadwaters of the stream, Frankfort, 21 July, 1916, *Fernald & Long 12338* (Gray Herb. and Mo. Bot. Gard. Herb.).

Knox Co.: Chickawaukie Pond, Rockland, *Fernald 1214* (Gray Herb.).

Lincoln Co.: muddy shore, Pemaquid River, in about 6 in. water, Bremen, 27 August, 1899, *Chamberlain* (Gray Herb.).

Kennebec Co.: cold spring-pool in margin of brook, Sydney, 18 August, 1916, *Fernald & Long 12339* (Gray Herb.); river margin, in mud, Waterville, 2 September, 1898, *Fernald 2824* (Gray Herb.); Cobbossee Contee Lake, Winthrop, August, 1898, *Battey* (Gray Herb.); Winthrop, 28 August, 1898, *Battey* (Gray Herb.).

Sagadahoc Co.: tidal mud flats of the river, Bowdoinham, 14–19 September, 1916, *Fernald & Long 12342* (Gray Herb. and Mo. Bot. Gard. Herb.); border of salt marsh, Back River Creek, Woolwich, 15 September, 1916, *Fernald & Long 12343* (Gray Herb.).

Franklin Co.: Bay Pond north of Bullhorse Pond, south end Great Pond, Industry, 14 August, 1894, *Fernald* (Mo. Bot. Gard. Herb. and Gray Herb.); cold spring entering North-

west Pond, n. Franklin Co., 14 July, 1895, *Coville 84* (U. S. Nat. Herb. and N. Y. Bot. Gard. Herb.); Wilson Stream, East Wilton, 11 August, 1894, *Fernald* (Gray Herb.).

Androscoggin Co.: river at Mechanics Falls, 28 August, 1897, *Allen* (Mo. Bot. Gard. Herb. and Gray Herb.); Lake Auburn, Auburn, 15 September, 1904, *Winslow* (Mo. Bot. Gard. Herb.); South Poland, 1893 and 1895, *Furbish* (Gray Herb.); Livermore Falls, *Furbish* (Gray Herb.).

Cumberland Co.: muddy bank, Androscoggin River, Brunswick, 1 August, 1894, *Davis* (U. S. Nat. Herb.); sandy bottom of Sand Pond, Baldwin, 30 August, 1916, *Fernald, Long & Norton 12337* (Gray Herb. and Mo. Bot. Gard. Herb.).

Oxford Co.: shallow water of brook, Buckfield, 8 August, 1894, *Allen* (Gray Herb.).

York Co.: in Newichawannnick River, N. Berwick, 25 September, 1897, *Parlin & Fernald 922* (Gray Herb.); rocky bed of Great Works River, No. Berwick, 25 September, 1897, *Fernald* (in part) (Gray Herb.).

New Hampshire: wiers on Lake Winnipiseogee, 19 September, 1856, *Engelmann* (Mo. Bot. Gard. Herb. and Gray Herb.), TYPE; at mouth of "Sucker Brook" and in Lake Sunapee, 17 July, 1903, *Waters* (Mo. Bot. Gard. Herb.); Newmarket, 19 August, 1899, *Eaton* (Mo. Bot. Gard. Herb. and Univ. Minn. Herb.); Country Pond, Newton, 18 August, 1896, *Eaton 441* (Mo. Bot. Gard. Herb. and U. S. Nat. Herb.); Alton Bay, 1894, *Eaton* (Mo. Bot. Gard. Herb.); Noyes Pond, Seabrook, 13 August, 1899, *Eaton ser. 2, 187* (Mo. Bot. Gard. Herb. and Univ. Minn. Herb.); pond on Lamprey River, Epping, August, 1896, *Eaton* (Mo. Bot. Gard. Herb.); wiers on Lake Winnipiseogee, 23 September, 1863, *Mann* (Mo. Bot. Gard. Herb., U. S. Nat. Herb., and Gray Herb.); Lake Winnipiseogee, 28 September, 1866, *Boott* (Mo. Bot. Gard. Herb. and Gray Herb.); Echo Lake, Franconia, 12 September, 1862, *Boott* (Mo. Bot. Gard. Herb. and Gray Herb.); Echo Lake, Franconia, 31 July, 1863, *Boott* (Mo. Bot. Gard. Herb. and Gray Herb.); Eagle Lake, Mt. Lafayette, alt. 4200 ft., 26 September, 1891, *E. & C. E. Faxon* (Gray Herb.); country pond, East Kingston, August, 1895, *Eaton* (Mo. Bot. Gard. Herb.); late form, out of water, East Kingston, 18 September, 1895, *Dodge*

(Gray Herb.); borders of pond, East Kingston, 6 October, 1895, *Eaton 699* (Mo. Bot. Gard. Herb. and Univ. Minn. Herb.); "Dismal Pool" near mouth of Saco River, White Mt., 26 August, 1882, *E. & C. E. Faxon 10* (Mo. Bot. Gard. Herb. and Gray Herb.); Saco Lake, Crawfords, 17 July, 1893, *E. & C. E. Faxon 4* (Gray Herb.); Ammonoosuc Lake, Crawfords, 17 July, 1893, *E. & C. E. Faxon 3* (Gray Herb. and N. Y. Bot. Gard. Herb.); submerged flats at Kingston, August, 1896, *Eaton* (Mo. Bot. Gard. Herb.); early form growing submersed, East Flats, East Kingston, 28 July, 1896, *Dodge* (Gray Herb.); Flats, East Kingston, 28 July, 1896, *Eaton* (Mo. Bot. Gard. Herb.); Epping, *Eaton 431* (Mo. Bot. Gard. Herb.); Epping, 12 August, 1896, *Eaton 425a* (Mo. Bot. Gard. Herb.); West Epping, *Eaton 482b* (Mo. Bot. Gard. Herb.); Pautuckaway Pond, Nottingham, 29 July, 1896, *Eaton 483a* (Mo. Bot. Gard. Herb.); East Kingston, 28 July, 1896, *Eaton 364* (Mo. Bot. Gard. Herb. and U. S. Nat. Herb.); sandy bottoms of ponds, East Kingston, August, 1895, *Eaton* (N. Y. Bot. Gard. Herb.); East Kingston, 6 July, 1896, *Eaton 239* (Mo. Bot. Gard. Herb.); Trickling Falls, East Kingston, 29 July, 1896, *Eaton* (Mo. Bot. Gard. Herb.); Rod Miller's, Seabrook, *Eaton* (Mo. Bot. Gard. Herb.); Conway Lake, 25 August, 1904, *Davenport* (Mo. Bot. Gard. Herb.); Lake Winnipisaukee, 10 September, 1910, *Sargent 27* (Gray Herb.); Gustin Pond, Marlow, 29 July, 1899, *Fernald 186* (in part) (Gray Herb.); clayey sand, shores of Thorndike Pond, 29 September, 1897, *Rand & Robinson 927* (Gray Herb.); Seabrook, September, 1895, *Eaton* (U. S. Nat. Herb. and Univ. Minn. Herb.); Gilmanton, 4 September, 1911, *Lunt 60* (Gray Herb.); shingly margin of Fish Pond, Columbia, Coos Co., 22 August, 1912, *Pease 13790* (Gray Herb.); sphagnous bogs, by small ponds near timber line, western slope of Mt. Lafayette, Franconia, 17–18 July, 1915, *Fernald & Smiley 11496* (Gray Herb.); Loutenstein, Asquam Lake, 13 August, 1914, *Gundersen* (Gray Herb.).

Vermont: Lake Dunmore, 1859, *Chapman* (Mo. Bot. Gard. Herb.); in small pond near summit of Mt. Mansfield, August, 1863, *Mann* (Gray Herb.); Lake of the Clouds, Mt. Mansfield, 10 August, 1876, *Pringle* (Mo. Bot. Gard.

Herb.); pond on Sterling Mt., 20 August, 1877, *C. E. Faxon 1* (Mo. Bot. Gard. Herb.); Notch Pond, Ferdinand, Essex Co., *Eggleston 1785* (Mo. Bot. Gard. Herb., Gray Herb., and N. Y. Bot. Gard. Herb.); Pike Pond, Stratton, August 6–10, 1900, *Eggleston 2201* (Mo. Bot. Gard. Herb., N. Y. Bot. Gard. Herb., and Gray Herb.); shallow water, Peacham, 14 August, 1884, *Blanchard* (N. Y. Bot. Gard. Herb. and Dudley Herb.); Foster's Pond, Peacham, September, 1881, *Blanchard* (Mo. Bot. Gard. Herb.); Stratton Plateau, Stratton, 6–10 August, 1900, *Eggleston 2201* (Dudley Herb.); Lake of the Clouds, Mt. Mansfield, 14 August, 1901, *Eggleston 2472* (U. S. Nat. Herb., Gray Herb., Mo. Bot. Gard. Herb. and Dudley Herb.); shallow muddy shores, Lake of the Clouds, Mt. Mansfield, 31 July, 1893, *Eggleston 699* (Mo. Bot. Gard. Herb. and Univ. Minn. Herb.); Lake of the Clouds, Mt. Mansfield, 8 August, 1877, *Faxon 2* (Mo. Bot. Gard. Herb.); same place and date, without number, *Faxon* (Gray Herb.); small pond, Lake of the Clouds, Mt. Mansfield, August, 1863, *Mann* (Mo. Bot. Gard. Herb. and Gray Herb.); Lake of the Clouds, 31 July, 1893, *Hinsdale & Eggleston* (Dudley Herb. and U. S. Nat. Herb.); Larger Lake of the Clouds, 15 July and 31 July, 1893, *Miller 1 & 2* (Gray Herb.); Pleiad Lake, alt. 2500 ft., Hancock, 13 September, 1896, *Brainerd* (Gray Herb.); Chittenden, 18 August, 1895, *Eggleston* (Univ. Minn. Herb.); Joe's Pond, W. Danville, 5 July, 1894, *Burbank, Grout & Eggleston* (U. S. Nat. Herb. and N. Y. Bot. Gard. Herb.); muddy shores of Pike's Mill Pond, Stratton, 10 August, 1894, *Grout* (N. Y. Bot. Gard. Herb.); Lake Champlain, north end of Isle La Motte, 2 September, 1879, *Pringle* (Mo. Bot. Gard. Herb., N. Y. Bot. Gard. Herb., and U. S. Nat. Herb.); North Pond, Stratton, 30 July, 1894, *Grout* (N. Y. Bot. Gard. Herb.); Lake Champlain, n. end of Isle La Motte, 19 July, 1878, *Pringle* (Mo. Bot. Gard. Herb.); muddy banks, Lower Haystack Pond, Wilmington, Windham Co., 6 October, 1912, *St. John 630* (Gray Herb.); Kelsey's Beach, in water 1–2 ft. deep, Lake Dunmore, Salisbury, 23 August, 1908, *Dutton 397* (Gray Herb.); Stony Pond, region of Pine Hill, Rutland, 25 July, 1909, *Dutton 198* (Gray Herb.); region Battell's Pond, alt. about 2500 ft., Hancock, 22 August, 1909, *Dutton 260* (Gray

Herb.); Connecticut River, Norwich, September, 1876, *Jesup* (N. Y. Bot. Gard. Herb.).

Massachusetts:

Essex Co.: Attitash, 27 June, 1896, *Eaton 197* (Mo. Bot. Gard. Herb.); muddy banks of Merrimac River, Newburyport, 1895, *Eaton* (Dudley Herb.); Attitash, 31 July, 1896, *Eaton 380* (Mo. Bot. Gard. Herb.); Kimballs Pond, Amesbury, 15 August, 1899, *Eaton 192* (Mo. Bot. Gard. Herb.); Kimballs Pond, Amesbury, 13 August, 1899, *Eaton* (Mo. Bot. Gard. Herb. and Univ. Minn. Herb.); Kimballs Pond, Amesbury, 13 August, 1896, *Eaton* (Mo. Bot. Gard. Herb.); Tuxbury's Pond, Amesbury, 19 September, 1897, *Eaton 919* (Mo. Bot. Gard. Herb.); Marshall's Pond, Amesbury, 13 August, 1903, *Eaton* (Mo. Bot. Gard. Herb.); Crane Pond, Bagfield, 6 July, 1893, *Lunt* (Gray Herb.); Bates Pond, Wenham, 29 July, 1896, *Eaton 377* (Mo. Bot. Gard. Herb.); Pleasant Pond, Wenham, *C. E. Faxon 6* (Mo. Bot. Gard. Herb.); Pleasant Pond, Wenham, without date or number, *C. E. Faxon* (Gray Herb.); Beaver Pond, Beverly, August, 1870, *Russell* (Mo. Bot. Gard. Herb.); bank of Merrimac, Newburyport, 12 September, 1895, *Eaton* (Mo. Bot. Gard. Herb. and Univ. Minn. Herb.); bank of Merrimac, Newburyport, August, 1895, *Eaton* (N. Y. Bot. Gard. Herb.); Chattwick's Pond, W. Boxford, 1 September, 1882, *Robinson* (Mo. Bot. Gard. Herb.); banks of Merrimac R., Newburyport, 12 September, 1897, *Eaton* (Univ. Minn. Herb.); Manchester and vicinity, without date, *Chamberlain* (N. Y. Bot. Gard. Herb.); muddy pool, Amesbury, 13 August, 1899, *Eaton* (Univ. Minn. Herb.); Ipswich River, Ipswich, 29 July, 1874 and 1875, *Morong* (N. Y. Bot. Gard. Herb.); Ipswich River, Ipswich, July, 1875, *Morong* (U. S. Nat. Herb.); East Andover, 1903, *Holt* (Gray Herb.); Wenham, *Collins* (Gray Herb.); pond on Skug River, above Sawmill Road, 22 September, 1903, *Pease 2775* (Gray Herb.).

Middlesex Co.: Woburn, 16 November, 1862, *without collector's name* (Mo. Bot. Gard. Herb.); Woburn, 3 September, 1866, *Boott* (Gray Herb.); Small Round Pond, Woburn, 8 September, 1867, *Boott* (Mo. Bot. Gard. Herb.); Small Round Pond, Woburn, 23 September, 1867, *Boott* (Mo. Bot. Gard. Herb.); Small Round Pond, Woburn, 5 August, 1860, *Boott*

(Mo. Bot. Gard. Herb. and Gray Herb.); Small Round Pond, Woburn, 29 September, 1867, *Boott* (Mo. Bot. Gard. Herb.); Small Round Pond, Woburn, 11 August, 1867, *Boott* (Mo. Bot. Gard. Herb. and Gray Herb.); Small Round Pond, Woburn, 20 October, 1867, *Boott* (Mo. Bot. Gard. Herb.); Small Round Pond, Woburn, 9 June, 1867, *Boott* (Mo. Bot. Gard. Herb.); Small Round Pond, Woburn, 2 September, 1866, *Boott* (Mo. Bot. Gard. Herb. and Gray Herb.); Small Round Pond, Woburn, 18 September, 1866, *Boott* (Mo. Bot. Gard. Herb., Gray Herb., and N. Y. Bot. Gard. Herb.); Small Round Pond, Woburn, 14 July, 1867, *Boott* (Mo. Bot. Gard. Herb.); Small Round Pond, Woburn, 15 & 22 August, 1869, *Boott* (Gray Herb.); Mystic Pond, without date, *C. E. Faxon* (Gray Herb.); Mystic Pond, 6 August, 1865, *Boott* (Mo. Bot. Gard. Herb. and Gray Herb.); Mystic Pond, 30 July, 1865, *Boott* (Gray Herb.); Mystic Pond, 2 September, 1866, *Boott* (Mo. Bot. Gard. Herb.); Mystic Pond, 3 September, 1866, *Boott* (Gray Herb.); Mystic Pond, 14 June, 1867, *Boott* (Mo. Bot. Gard. Herb.); Mystic Pond, Medford, without date, *Boott* (Gray Herb.); pond in Woburn, without date, *Davenport* (Gray Herb.); Mystic Pond, 29 August, 1869, *Boott* (N. Y. Bot. Gard. Herb.); Sherman's Pond, Waltham, 31 August, 1869, *Boott* (N. Y. Bot. Gard Herb.); Spot Pond, Stoneham, 19 August, 1899, *Rich* (Gray Herb.); Spot Pond, Stoneham, without date, *Collins* (Gray Herb.); Skug River, North Reading, 14 September, 1903, *Pease 2670* (Gray Herb.); submerged in running water, Ashland, 17 July, 1879, *Morong* (N. Y. Bot. Gard. Herb.); Nutting Pond, Billerica, 11 August, 1869, *Boott* (N. Y. Bot. Gard. Herb.); sandy margin of Heard's Pond, Wayland, 10 September, 1909, *Fernald* (Gray Herb.); Mystic Pond, near Bacon's, 10 September, 1876, *Boott* (N. Y. Bot. Gard. Herb.); Mystic Pond at Grover, 29 August, 1869, *Boott* (N. Y. Bot. Gard. Herb.); Mystic Pond, 29 August, 1882, *Perkins* (Gray Herb.); Mystic Pond, 4 July, 1867, *Boott* (Mo. Bot. Gard. Herb. and Gray Herb.); Mystic Pond, 1 September, 1867, *Boott* (Mo. Bot. Gard. Herb. and Gray Herb.); brook above gas works, Arlington, 1 September, 1867, *Boott* (Gray Herb.); Mystic Pond, mouth of Arlington Brook, 30 July, 1864, *Boott,* (Mo. Bot. Gard. Herb. and

N. Y. Bot. Gard. Herb.); Mystic Pond, mouth of Arlington Brook, 2 June, 1867, *Boott* (Mo. Bot. Gard. Herb.); along banks of Mystic Pond, 21 October, 1866, *Boott* (Mo. Bot. Gard. Herb.); Mystic Pond, 14 and 30 July, 1864, *Boott* (Gray Herb.); east side of Mystic Pond, 8 September, 1867. *Boott* (Mo. Bot. Gard. Herb.); west side of Mystic Pond, north of Brook, 12 July, 1868, *Boott* (Gray Herb.); south side of Spy Pond, Arlington, 5 and 9 September, 1867, *Boott* (Mo. Bot. Gard. Herb.); Spot Pond, 6 September, 1868, *Boott* (N. Y. Bot. Gard. Herb.); Spot Pond, Stoneham, 23 July, 1867, *Boott* (Mo. Bot. Gard. Herb.); Spot Pond, 18 November, 1866, *Boott* (U. S. Nat. Herb.); Horn Pond, Woburn, September, 1862, *Mann* (Gray Herb.); island in middle of Horn Pond, 11 July, 1867, *Boott* (Mo. Bot. Gard. Herb. and Gray Herb.); northwest side Horn Pond, 16 September, 1869, *Boott* (N. Y. Bot. Gard. Herb.); Fresh Pond, 17 September, 1867, *Boott* (Mo. Bot. Gard. Herb. and Gray Herb.); Concord Brook, 20 August, 1866, *Boott* (Mo. Bot. Gard. Herb.); Round Pond, Woburn, 1 October, 1874, *Davenport* (N. Y. Bot. Gard. Herb.); Hammond's Pond, Brookline, without date, *C. E. Faxon* (Mo. Bot. Gard. Herb.); Round Pond, Woburn, without date, *C. E. Faxon* (Mo. Bot. Gard. Herb.); Hammond's Pond, 1878, *Farlow* (Mo. Bot. Gard. Herb.); Tofit Swamp Brook, Lexington, 17 July, 1867, *Boott* (Gray Herb. and N. Y. Bot. Gard. Herb.); brook in Tofit Swamp, Lexington, 9 September, 1867, *Boott* (Mo. Bot. Gard. Herb. and Gray Herb.); South Natick, 14 July, 1879, *Morong* (Mo. Bot. Gard. Herb.); "entirely submerged in pool, South Natick", 13 August, 1883, *Morong* (N. Y. Bot. Gard. Herb.); ponds, West Cambridge, 1861, *Boott* (Mo. Bot. Gard. Herb.); Concord, in streams, September, 1863, *Mann* (Gray Herb.); Concord, 1 October, 1863, *Mann* (Mo. Bot. Gard. Herb.); Concord, without date, *Mann* (Gray Herb.); small pond in Winchester (formerly Woburn), August, 1876, *Morong 353* (U. S. Nat. Herb.); small pond in Winchester, 22 August, 1876, *Morong* (N. Y. Bot. Gard. Herb.); brooks, slow moving water, Melrose, 8 July, 1875, *Morong* (N. Y. Bot. Gard. Herb.); in running water, Melrose, September, 1876, *Morong* (U. S. Nat. Herb.); Sandbury River, Framingham, September,

1894, *Smith* (Mo. Bot. Gard. Herb.); from a canal in So. Natick, water about 1 ft. deep, 25 June, 1879, *Morong* (N. Y. Bot. Gard. Herb. and Mo. Bot. Gard. Herb.); entirely submerged, Charles R., So. Natick, 4 August, 1879, *Morong* (N. Y. Bot. Gard. Herb.).

Norfolk Co.: Neponset River, Readville, 28 July, 1870, *Boott* (N. Y. Bot. Gard. Herb.); Highland Lake, Norfolk, 1 August, 1909, *Ware 724* (Mo. Bot. Gard. Herb.); Hammond's Pond, Brookline, *C. E. & W. Faxon 8* (Gray Herb.); Lake Massapoag, 17 October, 1897, *Greenman 2314* (Mo. Bot. Gard. Herb.); Dedham, growing in shallow water, mud bottom, 24 July, 1902, *Forbes* (Gray Herb.); Lake Massapoag, 11 September, 1903, *Eaton* (Mo. Bot. Gard. Herb.); in Sutton's Brook, at its junction with Charles River, Needham, 12 July, 1885, *Fuller* (Gray Herb.).

Bristol Co.: Mulberry Brook, Easton, 16 August, 1903, *Eaton* (Mo. Bot. Gard. Herb.); Flyaway Pond, No. Easton, 15 July, 1903, *Eaton* (Mo. Bot. Gard. Herb.); Canoe River, 2 August, 1903, *Eaton* (Mo. Bot. Gard. Herb.); Watson's Pond, Taunton, 12 July, 1903, *Eaton* (Mo. Bot. Gard. Herb.); few stations in stream, Swansea, 16 August, 1912, *Sanford 38* (Gray Herb.).

Worcester Co.: Massapoag Lake, 11 September, 1903, *Eaton* (Mo. Bot. Gard. Herb.); Uxbridge, 30 August, 1864, *Robbins* (Mo. Bot. Gard. Herb. and Gray Herb.); "river," Uxbridge, 1 August, 1867, *Robbins* (N. Y. Bot. Gard. Herb.); pond, Grafton, 27 July, 1866, *Robbins* (Mo. Bot. Gard. Herb. and N. Y. Bot. Gard. Herb.); pond connected with Blackstone River, 30 August, 1864, *Robbins* (Mo. Bot. Gard. Herb.); Uxbridge, 1845, *Robbins* (Mo. Bot. Gard. Herb.); Uxbridge, without date, *ex. herb. Robbins* (N. Y. Bot. Gard. Herb.); millpond, depth of 2–3 ft., Uxbridge, 30 August, 1866, *Robbins* (Mo. Bot. Gard. Herb.); Cohasset Brook, Southbridge, alt. 640 ft., 12 August, 1899, *Harper* (N. Y. Bot. Gard. Herb.); rocky bottom of Quenebang River, Sturbridge, alt. 540 ft., 23 July, 1899, *Harper* (Gray Herb.); Uxbridge, 31 August, 1907, *Eaton* (Mo. Bot. Gard. Herb.).

Franklin Co.: Ashfield Pond, Ashfield, 18 July, 1909, *Williams* (Gray Herb.).

Berkshire Co.: Lake Undine, Mt. Everett, 1 October, 1897, *N.*

L. Britton (N. Y. Bot. Gard. Herb.); same station and date, *E. G. Britton* (N. Y. Bot. Gard. Herb.); Spectacle Pond, Sandisfield, 29 June, 1912, *Hoffman* (Gray Herb.); Lake Undine, The Dome, Sheffield, 27 August, 1902, *Hoffman* (Gray Herb.).

Massachusetts, but not located on map: "Country Pond," 18 August, 1896, *Eaton 441* (Mo. Bot. Gard. Herb.); "Kenoza Lake," 12 September, 1897, *Eaton 913* (Mo. Bot. Gard. Herb.); Pinkapog Pond, 27 August, 1869, *Boott* (N. Y. Bot. Gard. Herb.).

Connecticut: Greystone, 30 August, 1907, *Eaton* (Mo. Bot. Gard. Herb.); upper end Selden's Creek, 5 August, 1905, *Graves 142* (Mo. Bot. Gard. Herb.); Mashapang Pond, Union, 20–25 August, 1902, *Bissell* (Mo. Bot. Gard. Herb.); Lyme, 13 August, 1900, *Graves* (Mo. Bot. Gard. Herb.); Selden's Cove, Lyme, 29 August, 1901, *Bissell* (Gray Herb.); Selden's Cove, Lyme, 29 August, 1901, *Graves* (Mo. Bot. Gard. Herb.); submerged on sandy bottom, Selden's Cove, Lyme, 11 September, 1902, *Graves 1* (Gray Herb.); W. Goshen, July, 1891, *Underwood* (Mo. Bot. Gard. Herb. and Gray Herb.); Great Brook near Poquonnock, "Lake Marshapog, Litchfield," 1882, *Underwood* (Mo. Bot. Gard. Herb.); shallow water of pond at Graystone, Plymouth, 6 September, 1903, *Bissell* (in part) (Gray Herb.); Graystone, 30 August, 1907, *Eaton* (Mo. Bot. Gard. Herb.).

New York: Niagara River, below Buffalo, 3 September, 1866, *Clinton* (Mo. Bot. Gard. Herb. and Gray Herb.); Niagara River, September, 1866, *Clinton* (Gray Herb. and N. Y. Bot. Gard. Herb.); Oneida Lake, *Gilbert* (Mo. Bot. Gard. Herb.); Niagara River, below Buffalo, 1865, *Clinton* (N. Y. Bot. Gard. Herb.); at outlet of Lake Luzerne, Warren Co., 24 August, 1867, *Clinton* (Mo. Bot. Gard. Herb.); lake on Catskill Mts., July, 1868, *Canby* (Mo. Bot. Gard. Herb.); lakelet, Catskill Mts., 19 September, 1866, *Clinton* (Mo. Bot. Gard. Herb. and Gray Herb.); west of Lake George, shallow pool, 20 July, 1862, *Les Lesquereux* (Mo. Bot. Gard. Herb.); Niagara River, 2 September, 1862, *Clinton* (Mo. Bot. Gard. Herb.); submerged banks, Oneida Lake, 20 July, 1879, *Paine* (Mo. Bot. Gard. Herb.); Greenwood Lake, Orange Co., 15

July, 1876, *Schrenk* (Mo. Bot. Gard. Herb.); Southern Pond, Catskill Mts., 1866, *Clinton* (Gray Herb.); Catskill Lake, June, 1888, *Canby* (Mo. Bot. Gard. Herb.); submerged on east shore of Cayuta Lake, Schuyler Co., 23 August, 1893, *Clinton* (U. S. Nat. Herb.); Lake Tear of the Clouds, Mt. Marcy, 6 September, *Britton* (N. Y. Bot. Gard. Herb.); Lake Mahopac, 4 October, 1891, *Morong* (N. Y. Bot. Gard. Herb.); Upper Ansable Pond, Adirondacks, 3 September, 1894, *Britton* (N. Y. Bot. Gard. Herb.); on sand bottom, Lake Placid, 6 September, 1896, *Dr. & Mrs. Britton* (N. Y. Bot. Gard. Herb.); Clear Lake, south of Elk Lake, Adirondacks, 4 September, 1894, *Britton* (N. Y. Bot. Gard. Herb.); Chilson Lake, 31 August, 1900, *Dr. & Mrs. Britton* (N. Y. Bot. Gard. Herb.); Cinnamon Lake, Steuben Co., 31 August, 1898, *Barber 394* (Mo. Bot. Gard. Herb.); submerged on sandy bottom, Duck Lake, Conquest, Cayuga Co., 1 July, 1916, *Eames, Metcalf & Wiegand 5445* (Gray Herb.).

New Jersey: submerged on sandy bottom, Budd's Lake, Morris Co., 2 September, 1904, *Mackenzie 1025* (Mo. Bot. Gard. Herb.); shores of Tom's River, Ocean Co., 18 September, 1873, *Parker* (Gray Herb.); submerged in salt water, Tom's River, Ocean Co., 18 September, 1873, *Martindale* (Mo. Bot. Gard. Herb.); bed of Tom's River, Ocean Co., 16 September, 1867, *Parker* (Mo. Bot. Gard. Herb. and Gray Herb.); submerged, Tom's River, Ocean Co., 17 September, 1867, *Smith* (Mo. Bot. Gard. Herb.); growing abundantly on submerged sand bars, in Tom's River, 15 September, 1867, *Smith* (Gray Herb.); Lake Hopotong, Morris Co., 25 September, 1869, *Porter 1953* (Mo. Bot. Gard. Herb.); Ridgewood, 21 July, 1880, *Brown* (Mo. Bot. Gard. Herb.).

Pennsylvania: Great Pond, Pocono Mt., Carbon Co., 7 August, 1867, *Canby* (Mo. Bot. Gard. Herb.); Great Lake, Carbon Co., 7 August, 1867, *Porter* (Mo. Bot. Gard. Herb.); Montrose, Susquehanna Co., 24 May, 1869, *Garber* (Mo. Bot. Gard. Herb.); Presque Isle, Erie, September, 1868, *Garber* (Mo. Bot. Gard. Herb.); Erie, July, 1868, *Garber* (Gray Herb.); Presque Isle, Erie, 28 July, 1868, *Garber* (Mo. Bot. Gard. Herb. and N. Y. Bot. Gard. Herb.); Delaware R. at Monroe, Bucks Co., 24 July, 1886, *Ruth* (Univ. Minn. Herb.); Bowman's Pond, Wyoming, 17 July, 1897, *Brown*

(U. S. Nat. Herb.); Poyntelle Pond, Wayne Co., 20 and 21 July, 1900, *Clute* (Mo. Bot. Gard. Herb.); Coxtown Pond, Wayne Co., 20 July, 1900, *Clute* (Mo. Bot. Gard. Herb.).

Ontario: Partridge Lake, 50 mi. northeast of Bellesville, Hastings, 21 August, 1863, *John Macoun* (Mo. Bot. Gard. Herb.); Hastings, 12 July, 1870, *John Macoun* (Mo. Bot. Gard. Herb.); head of ship canal, Sault Ste. Marie, 7 August, 1869, *John Macoun* (Mo. Bot. Gard. Herb.); in Lake Superior, shores of Michipicoten Isl., at Grierson's Landing, 24 July, 1869, *John Macoun* (Mo. Bot. Gard. Herb.); water, Nipigon River, 21 July, 1884, *John Macoun* (Gray Herb. and N. Y. Bot. Gard. Herb.); on gravel bottom, Orient Bay, Lake Nipigon, midway of east shore of bay, in 2 ft. water, 23 July, 1911, *O. E. & G. K. Jennings 6582* (Gray Herb. and U. S. Nat. Herb.); marshes, Lake Nipigon, 10 July, 1884, *John Macoun* (Gray Herb.); Nipigon River, 23 July, 1884, *John Macoun 14222* (Gray Herb. and N. Y. Bot. Gard. Herb.); mouth of Nipigon River, Lake Superior, 23 June, 1884, *John Macoun* (N. Y. Bot. Gard. Herb.); Catfish Lake, Algonquin Park, 23 July, 1900, *John Macoun 24942* (N. Y. Bot. Gard. Herb.); Opeonga Lake, Algonquin Park, 16 August, 1900, *John Macoun 24940* (N. Y. Bot. Gard. Herb.).

Michigan: Belle Isle, Detroit River, 6 August, 1871, *Gillman* (Mo. Bot. Gard. Herb.); Gogebic Co., summer, 1919, *Darlington* (Mo. Bot. Gard. Herb.).

Ohio: submerged in 10–20″ water, Brady's Lake, Portage Co., 15–30 June, 1913, *Hopkins* (U. S. Nat. Herb., N. Y. Bot. Gard. Herb., and Gray Herb.).

Wisconsin: Plum Lake, Sayner, Vilas Co., summer 1918, *Goodspeed* (Mo. Bot. Gard. Herb.); muddy shore, Three Lakes. Oneida Co., 13 August, 1918, *Hoffman* (Mo. Bot. Gard. Herb.); rocky bottom, Crooked Lake, Three Lakes, Oneida Co., 26 August, 1918, *Hoffman* (Mo. Bot. Gard. Herb.).

Minnesota: Mountain Lake, Cook Co., 21 August, 1901, *MacMillan, Brand & Lyon 177* (Mo. Bot. Gard. Herb. and Univ. Minn. Herb.); small lake on Gunflint trail near 13 mile post, Cook Co., 14 August, 1901, *MacMillan, Brand & Lyon 71* (Mo. Bot. Gard. Herb. and Univ. Minn. Herb.); Mud Lake, Cook Co., 20 August, 1901, *MacMillan, Brand & Lyon 70* (Mo. Bot. Gard. Herb.); Echo Lake, Mahtomedi, 14

August, 1902, *Wheeler 1227* (Univ. Minn. Herb.); Echo Lake, 16 August, 1904, *Lyon 874, 875,* & *876* (Univ. Minn. Herb.); South Lake, Cook Co., 19 August, 1901, *MacMillan, Brand & Lyon 146* (Univ. Minn. Herb.); Mud Lake, Cook Co., 22 August, 1901, *MacMillan, Brand & Lyon 198* (Univ. Minn. Herb.); Kove Lake, Cook Co., 20 August, 1901, *MacMillan, Brand & Lyon 171* (Univ. Minn. Herb.); Mud Lake, Cook Co., 20 August, 1901, *MacMillan, Brand & Lyon 170* (Univ. Minn. Herb.); Long Lake, Vermilion Lake, Lat. 48°, 25 July, 1886, *Arthur, Bailey & Holway B413* (Univ. Minn. Herb. and Gray Herb.); Vermilion Lake, 18 July, 1886, *Arthur, Bailey & Holway B 87* (Univ. Minn. Herb. and Gray Herb.).

Idaho: Bitter Root Forest Reserve, alt. 1800 m., 1 September, 1897, *Leiberg 71* (Mo. Bot. Gard. Herb.); Bitter Root Forest Reserve, Head of Bear Creek, alt. 2250 m., 1 September, 1897, *Leiberg 2971* (U. S. Nat. Herb.).

Colorado: Seven Lakes, 3500 m., 1 September, 1902, *R. E. & E. S. Clements 493,1* (Mo. Bot. Gard. Herb., U. S. Nat. Herb., and Gray Herb.).

Utah: lake near head of Bear River, Uintah Mts., 4 August, 1869, *Watson 1371* (Mo. Bot. Gard. Herb., U. S. Nat. Herb., and N. Y. Bot. Gard. Herb.).

Vancouver Island: Prospect Lake near Victoria, 25 July, 1908, *John Macoun 86379* (Gray Herb. and N. Y. Bot. Gard. Herb.); Alberni, 10 August, 1887, *John Macoun 14217* (Gray Herb.); Sproat Lake, 12 August, 1887, *John Macoun 14218* Gray Herb.); Sooke, 2 August, 1893, *John Macoun 14215* (Gray Herb.); Sooke, 2 August, 1893, *John Macoun 532* (Mo. Bot. Gard. Herb.); salt marsh, Somas River, 2 August, 1887, *John Macoun 14216* (Gray Herb.); in mud, Somas River, Alberni, with Limosella and Lilaea, 20 June, 1916, *Henry 9082* (Gray Herb.).

Washington: shallow ponds, alt. 6000 ft., Chiquash Mts., Skaimania Co., 16 August, 1900, *Suksdorf 2210* (Mo. Bot. Gard. Herb.); in lake, alt. 5000 ft., Mt. Rainier, August, 1895, *Piper 2131* (Mo. Bot. Gard. Herb., N. Y. Bot. Gard. Herb., and Gray Herb.); (lake 2 ft. deep volcanic ash) Mirror Lake, Mt. Rainier, 23 August, 1901, *Flett 1929x* (Mo. Bot. Gard. Herb., N. Y. Bot. Gard. Herb., and U. S. Nat. Herb.);

Reflection Lake, Mt. Rainier, 20 July, 1907, *Cowles 776* (Mo. Bot. Gard. Herb.); Lake Chelan, 22 September, 1897, *Gorman 715* (Gray Herb.); in Bitter Lake, near Seattle, July, 1891, *Piper 1117* (N. Y. Bot. Gard. Herb.).

California: at alt. 8000 ft., Mountain Lakes, head of Trinity River, 1 September, 1882, *Pringle* (Mo. Bot. Gard. Herb., U. S. Nat. Herb., and Gray Herb.); Castle Lake (near Scott's Mountain), mountains about headwaters of Sacramento River, scattered in gravelly bottom in 2–6 ft. water, 14 August, 1881, *Pringle* (Mo. Bot. Gard. Herb. and Gray Herb.).

42a. Forma **robusta** Pfeiffer, comb. nov.

I. echinospora var. *robusta* Engelm. Trans. St. Louis Acad. Sci. 4: 380. 1882.

I. echinospora Braunii f. *robusta* Clute, Fern Allies, 221, 258. 1905.

I. Gravesii Eaton, Fernwort Papers, 14. 1900.

I. valida var. *Gravesii* Clute, Fern Allies, 343. 1905.

Stouter than the species, with leaves as numerous as 75, 12–15 cm. long; stomata usually numerous, more so than in the species.

Specimens examined:

Vermont: Lake Champlain, north end of Isle La Motte, 2 September, 1879, *Pringle* (Mo. Bot. Gard. Herb. and Gray Herb.), TYPE; Lake Champlain, 19 July, 1878, *Pringle* (Mo. Bot. Gard. Herb.).

Connecticut: Tyler's Pond, near the outlet, W. Goshen, August, 1883, *Underwood* (Mo. Bot. Gard. Herb.); Tyler's Pond, W. Goshen, August, 1889, *Underwood & Cook* (N. Y. Bot. Gard. Herb.); gravelly and sandy tidal shores, Selden's Cove, Lyme, 31 August, 1900, *Graves* (Mo. Bot. Gard. Herb. and U. S. Nat. Herb.); same, *Graves 145* (Mo. Bot. Gard. Herb.); submerged, growing in mud, Selden's Cove, Lyme, 29 August, 1901, *Graves* (Mo. Bot. Gard. Herb. and Gray Herb.); Selden's Cove, Lyme, 27 August, 1907, *Eaton* (Mo. Bot. Gard. Herb.); shallow water of pond at Graystone, Plymouth, 6 September, 1903, *Bissell* (Mo. Bot. Gard. Herb. and Gray Herb.); Bristol, 1888, *Bishop* (U. S. Nat. Herb.);

Stratford, plentiful locally in sandy gravel of tidal flats of Housatonic River, 29 September, 1919, *Eames 9671* (Gray Herb.).

Plants described by Eaton as *I. Gravesii* have the appearance of robust forms of *I. Braunii,* are similar in abundance of stomata, and appear like immature specimens in spore markings. In cases where mature spores have been found in the soil, they prove to have the spines characteristic of *I. Braunii,* as well as the size. This is true of the specimens reported above from Connecticut, all of which have been collected at about the same season of the year.

There is one other possible position for this Connecticut material, if the assumption that it is immature proves to be unfounded. Young megaspores of the echinate group have very much the appearance that all the spores of *I. Eatoni* Dodge show. In habit, this stout form is enough like the latter to suggest a possible connection in this direction. Experimental work and collections through a longer interval of the fruiting season should clear up this doubtful form.

42b. Var. **maritima** (Underw.) Pfeiffer, comb. nov.

I. maritima Underw. Bot. Gaz. **13**: 94. 1888.

I. echinospora var. *maritima* Eaton, Fern Bull. **13**: 52. 1905.

I. Macouni Eaton, Fern Bull. **8**: 12. 1900.

Corm 2-lobed; leaves 7–15, 3–12 cm. long, green, chiefly slender, with fine-pointed tips and rather wide membranaceous border at base; stomata numerous; peripheral strands lacking; ligule triangular, little longer than wide; sporangia globose to oblong, 3–4 mm. long, with velum usually narrow, sometimes covering ½ of sporangium; megaspores white, chiefly 380–500 μ, rarely 600 μ, in diameter, usually densely marked with stout blunt spines, sometimes confluent into toothed ridges; microspores 30–39 μ long, chiefly papillose.

Distribution: Atkah and Vancouver Islands, Washington.

Specimens examined:

Aleutian Archipelago: pools in Atkah Isl., Behring Sea, 26 August, 1891, *Macoun 14227* (Mo. Bot. Gard. Herb. and Gray Herb.).

Vancouver Island: Alberni, Barclay Sound, August, 1887, *J. Macoun* (Mo. Bot. Gard. Herb.); Great Central Lake, 2 July,

1907, *Rosendahl 2050* (Mo. Bot. Gard. Herb., Gray Herb., U. S. Nat. Herb., and Univ. Minn. Herb.).

Washington: lake 2 ft. deep (volcanic ash), Mirror Lake, Mt. Rainier, 23 August, 1901, *Flett 1930* (Mo. Bot. Gard. Herb. and N. Y. Bot. Gard. Herb.).

It seems possible that this is but a form of *I. Braunii* Dur. growing under rather hard conditions. The distinguishing features are the large microspores with their papillose markings, in contrast to the usual smooth *I. Braunii* spores of 35 μ or less; the more numerous stomata, which are probably due to greater exposure; and the narrow velum, a feature which is shared, however, by most western specimens of *I. Braunii.*

43. I. truncata Clute, Fern Allies, 222–223, 260. 1905.

I. echinospora var. *truncata* Eaton in Gilbert, List N. Am. Pterid. **10**: 27. 1901.

Corm 2-lobed; leaves 20–40, 6–13 cm. long, stout, rather rigid, finely tapering, with almost setaceous apex and wide membranaceous margin at base; stomata numerous; peripheral strands lacking; ligule short-triangular; sporangium oblong, 4–6 mm. long, marked profusely with brown patches of sclerenchyma cells; velum covering about ¼–½ of sporangium; megaspores white, 430–520 μ, rarely 680 μ, in diameter, marked with numerous blunt spines; microspores 27–33 μ long, papillose.

Distribution: Alaska, Vancouver Island.

Specimens examined:

Alaska: Kodiak, 20 July, 1899, *Coville & Kearney Jr. 2336 & 2337* (Mo. Bot. Gard. Herb. and U. S. Nat. Herb.), TYPE; Kodiak, 20 July, 1899, *Fernow 2640* (Mo. Bot. Gard. Herb.).

Vancouver Island: Sproat Lake, *J. Macoun* (Mo. Bot. Gard. Herb.); Sproat Lake, fresh water, 13 August, 1887, *J. Macoun 5* (N. Y. Bot. Gard. Herb.).

Doubtful: *Coville & Kearney 386,* New Metlakatla, Annette Isl., Alaska, 4 June, 1899.

In the spinulose megaspores there is as wide a variation in size, number, and arrangement of spines as in *I. Braunii* Dur. with a marked tendency toward elongated, densely crowded, rather tuberculate structures. For the close arrangement the

only rival among the echinate forms is *I. Brochoni* Motel., in which the spines are far sharper.

Most of the Alaskan material is immature, but in some of the specimens mature spores can be found in the soil. The collection of Coville & Kearney 2336 appears to be made of smaller plants of the species, their 2337 of larger specimens, with no notable differences in spores, sculpture, etc.

Sect. 3. Cristatae

§ 3. **Cristatae.** Forms with 2 or 3-lobed corms; producing megaspores with tubercles or spines, somewhat extended into ridges, tending toward branching crests on basal face; microspores rough or smooth.

Key to Species

A. Corms 3-lobed.
  a. Leaves very slender ---------- *44. I. tripus*
  b. Leaves stout, mucronate ---------- *45. I. Savatieri*
B. Corms 2-lobed.
  a. Amphibious forms, with stomata; peripheral strands present or absent.
    α. Megaspores with very crowded prominences.
      I. Leaves numerous (25–200), usually with peripheral strands ---------- *46. I. Eatoni*
      II. Leaves few (8–25), peripheral strands lacking ---------- *47. I. saccharata*
    β. Megaspores with less densely crowded prominences.
      I. Sculpture consisting of spines somewhat extended to form jagged crests.
        1. Smaller form, leaves 10–30, 9–30 cm. long ---------- *48. I. riparia*
        2. Larger form, leaves 15–75, 10–45 cm. long ---------- *48a. I. riparia* var. *canadensis*
      II. Sculpture consisting of tubercles somewhat extended to form rounded ridges.
        1. Leaves long, more than 16 cm., with peripheral strands ---------- *49. I. Pringlei*
        2. Leaves short, less than 8 cm., lacking peripheral strands ---------- *50. I. Flettii*
  b. Submerged forms, lacking stomata and peripheral strands.
    α. Velum narrow, covering about ⅓ of sporangium.
      I. Megaspores with somewhat confluent, but little anastomosing, crests ---------- *51. I. lacustris*
      II. Megaspores with crests, forming irregular network on basal face ---------- *52. I. occidentalis*
    β. Velum wider, covering ⅓–⅔ of sporangium ---------- *53. I. Piperi*

44. I. tripus A. Br. Monatsber. K. Akad. Wiss. Berlin, 544. 1868; Motel. & Vendr. Actes Soc. Linn. Bord. **36**: 361. 1883.

I. phaeospora Dur. Bull. Soc. Bot. Fr. **9**: 103. 1864. *fide* Motel. & Vendr.

Calamaria tripus Kuntze, Rev. Gen. Pl. 2: 828. 1891-93.

Corm conspicuously 3-lobed; bulb of leaves small, bound by the dark black remains of dying leaves; leaves very slender, not narrowed above, somewhat obtuse and tough, opaque; stomata present; peripheral strands absent (?); ligule elongate-deltoid; velum none (beyond the acute edge of the fovea); sporangium without border, pale, becoming dark ashy, beautifully marked with few schlerenchyma cells; megaspores 400–460 μ, dark when wet or dry, meandriform-roughened on all faces; microspores 35–40 μ long, dark with loose exospore, somewhat wing-crested.

Distribution: Swan River, Australia.

Description from Braun.

45. I. Savatieri Franchet, Bull. Soc. Bot. Fr. **31**: 395. 1884; Baker, Fern Allies, 133. 1887.

Calamaria Savatieri Kuntze, Rev. Gen. Pl. 2: 828. 1891-93.

Corm obscurely 3-lobed, about 15–20 mm. in diameter; bulb coarse, 2–3 cm. in diameter, bearing loosely imbricated bases of leaves; leaves stout, subtetragonous, mucronate, about 20 cm. long in submerged forms, much shorter (hardly 6 cm.) in emersed plants, very coarse and rigid, broad (7–10 mm. at base), with wide membranaceous margin; sporangium small, hardly 4 mm. long, ovate or suborbicular, with narrow area; ligule ovate-deltoid, rough, fuscous; velum incomplete, covering 1/3–3/4 of sporangium; megaspores white, rough all over surface, marked finely with anastomosing ridges, more or less elevated; microspores brown, very finely muricate or almost smooth, cristate on one side.

Distribution: Patagonia, lakes in vicinity of Puerto Bono, Straits of Magellan.

Description from Franchet.

46. I. Eatoni Dodge, Ferns & Fern Allies of N. Eng. 39. 1896; Bot. Gaz. **23**: 32–39. *pl. 4–5.* 1897; Underwood, Native Ferns and Allies, 146. 1900.

I. valida Clute, Fern Allies, 236, 260. 1905.

Corm 2-lobed; leaves 25–200, 10–60 cm. in length, much shorter in summer (10–15 cm. long), coarser in spring forms; stomata numerous; peripheral strands variable in number, some-

times wanting; sporangia oblong, 6–11 mm. long, brown-spotted, 1/6–1/4 covered by velum; megaspores white, 396-520 μ, rarely more, in diameter, with irregular commissural ridges and with faces marked very irregularly by crowded short meandriniform elevations, sometimes with rounded teeth; microspores 25–35 μ long, smooth to slightly papillose.

Distribution: New Hampshire, Massachusetts, New Jersey.

Specimens examined:

New Hampshire: shore of pond, Trickling Falls, Kingston, August, 1895, *Dodge* (Mc. Bot. Gard. Herb. and Gray Herb.), TYPE; flats at Kingston, August, 1896, *Eaton* (Mo. Bot. Gard. Herb.); Kingston, 9 September, 1897, *Eaton* (Mo. Bot. Gard. Herb. and Gray Herb.); sloping bank of a pond, out of water most of the year, in mixed mud and sand, East Kingston, September, 1895, *Herb. Eaton* (Mo. Bot. Gard. Herb. and N. Y. Bot. Gard. Herb.); East Kingston, August, 1895, *Dodge* (Mo. Bot. Gard. Herb.); "East Kingston, on Powow River, shores of pond, fruiting out of water," 6 October, 1895, *Eaton* (Mo. Bot. Gard. Herb.); East Kingston, 26 July, 1896, *Eaton 351* (Mo. Bot. Gard. Herb.); East Kingston, August, 1896, *Dodge* (Mo. Bot. Gard. Herb. and N. Y. Bot. Gard. Herb.); East Kingston, 8 September, 1896, *Eaton 589* (Mo. Bot. Gard. Herb.); "The flats," East Kingston, 28 July, 1896, *Dodge* (Gray Herb.); East Kingston, August, 1896, *Eaton 163* (N. Y. Bot. Gard. Herb.); East Kingston, 9 September, 1897, *Eaton* (Mo. Bot. Gard. Herb.); East Kingston, 10 August, 1900, *Dodge* (Mo. Bot. Gard. Herb.); submersed, Kingston, August and September, 1897, *Eaton 898* (Mo. Bot. Gard. Herb.); grown in pond at Seabrook from plant collected at Kingston, 1900, *Eaton* (Mo. Bot. Gard. Herb.); West Epping, *Eaton 482C* (Mo. Bot. Gard. Herb.); Epping, 12 August, 1896, *Eaton 427* (Mo. Bot. Gard. Herb.); Lamprey River, Epping, August, 1897, *Eaton* (Mo. Bot. Gard. Herb.); Newmarket, 19 August, 1899, *Eaton 217* (Mo. Bot. Gard. Herb.).

Massachusetts: Tuxbury's Pond, Amesbury, 19 September, 1898, *Eaton 919* (Mo. Bot. Gard. Herb.); Parker River, *Dodge* (Mo. Bot. Gard. Herb.); Long Pond, North Easton, 23 September, 1903, *Eaton* (Mo. Bot. Gard. Herb.); without

location, September 16, 1902, *Eaton* (Mo. Bot. Gard. Herb.).

New Jersey: Morris Pond, 11 September, 1890, *Britton* (N. Y. Bot. Gard. Herb.); in water 1 ft. deep, Morris Pond, 14 September, 1887, *Britton* (N. Y. Bot. Gard. Herb.).

47. **I. saccharata** Engelm. in Gray, Manual, ed. 5, 676. 1867; Baker, Jour. Bot. 18: 69. 1880; Motel. & Vendr. Actes Soc. Linn. Bord. 36: 356. 1883; Engelm. Trans. St. Louis Acad. Sci. 4: 382. 1882; Eaton in Gray, Manual, ed. 7, 60. 1908; Maxon in Britton and Brown, Ill. Fl. 1: 52. 1913.

I. saccharata var. *Palmeri* Eaton, Proc. Biol. Soc. Wash. 14: 49. 1901.

I. saccharata var. *reticulata* Eaton, Proc. Biol. Soc. Wash. 14: 49. 1901.

Calamaria saccharata Kuntze, Rev. Gen. Pl. 2: 828. 1891-93.

Corm 2-lobed, small, much flattened; leaves 8–25, rarely 40, 6–15 cm. long, slender, curved, olive-green, with membranaceous margin at base, soon disappearing above; stomata numerous; peripheral strands none; ligule small, cordate at base; sporangium small, 3–5 mm. long, almost as wide as long, with narrow velum (covering less than 1/5 of sporangium); megaspores white, 400–520 μ in diameter, marked with very irregular, crowded, more or less discontinuous ridges with prominences somewhat blunt or granular; microspores 23–29 μ long (rarely 32), almost smooth.

Distribution: Delaware, Maryland, District of Columbia, Virginia.

Specimens examined:

Delaware: near Seaford, shores of Nanticoke River, Sussex Co., August, 1874, *Canby* (Mo. Bot. Gard. Herb., Gray Herb., and U. S. Nat. Herb.).

Maryland: on tidal mud, Salisbury, shores of Wicomico River, 28 August, 1867, *Canby* (Mo. Bot. Gard. Herb. and U. S. Nat. Herb.), TYPE; shores of Wicomico River below Salisbury, 8 September, 1866, *Canby* (Mo. Bot. Gard. Herb. and Gray Herb.); tidal mud, Salisbury, 28 August, 1867, *Canby* (Mo. Bot. Gard. Herb. and U. S. Nat. Herb.); shore of Wicomico River near Salisbury, 1 September, 1867, *Canby* (Gray Herb.); gravelly shore of Wicomico River, Salisbury, 1 Oc-

tober, 1868, *Commons* (U. S. Nat. Herb. and Gray Herb.); Salisbury, 1869, *Canby* (Mo. Bot. Gard. Herb.); "Maryland," September, 1870, *Canby* (Gray Herb.); Notley Hall, 1894, *Coville 32* (Gray Herb., U. S. Nat. Herb., and N. Y. Bot. Gard. Herb.); Wicomico River, 14 September, 1895, *Palmer* (Mo. Bot. Gard. Herb.); Kent Co., Lloyd's Creek, Sassafras River, 12 August, 1895, *Palmer* (Mo. Bot. Gard. Herb., Gray Herb., and U. S. Nat. Herb.); same, 29 July, 1896 (Mo. Bot. Gard. Herb.); tidal track, reddish sand, capped lightly with mud, Elk River (about 80 mi. north of Nanticoke and Wicomico River), 1894, *Palmer* (Mo. Bot. Gard. Herb.); Town Point, Elk River, 30 July, 1896, *Palmer* (Mo. Bot. Gard. Herb.); Cabin Johns Creek, 21 July, 1896, *Palmer* (Mo. Bot. Gard. Herb. and U. S. Nat. Herb.); Cabin Johns Creek, Elk River, 31 July, 1896, *Palmer* (U. S. Nat. Herb.); between tides, rather common among rocks in sand, ½ mi. southwest of Havre de Grace, 19 July, 1902, *Shull 66* (Mo. Bot. Gard. Herb., Gray Herb., and U. S. Nat. Herb.); ¼ mi. south of Havre de Grace, 19 July, 1902, *Shull 67* (U. S. Nat. Herb.); mouth of Gunpowder River, 2 September, 1902, *Shull 296* (Mo. Bot. Gard. Herb., Gray Herb., and U. S. Nat. Herb.); 1/3 mi. above mouth of Little Gunpowder River, in sand, 3 September, 1902, *Shull 305* (Mo. Bot. Gard. Herb., Gray Herb., and U. S. Nat. Herb.).

Washington, D. C.: shores of Anacostia River, opposite Navy Yard, 1 September, 1900, *Steele* (Mo. Bot. Gard. Herb., Gray Herb., and U. S. Nat. Herb.); tide mud, 5 August, 1898, *Steele* (Gray Herb.).

Virginia: Hunting Creek, by bridge near its mouth, 22 July, 1888, *Vasey & Coville* (U. S. Nat. Herb.); shore of Potomac at the foot of the Mt. Vernon estate, 4 July, 1889, *Coville* (Mo. Bot. Gard. Herb. and U. S. Nat. Herb.); Hunting Creek, 1 mi. south of Alexandria, 7 September, 1901, *Maxon 432* (U. S. Nat. Herb.); 1 mi. south of Alexandria, at right hand of wagon bridge over Hunting Creek, an arm of the Potomac, in sand or gravel, in 6 in. water, exposed at ebb tide, 16 September, 1906, *Maxon 3886* (U. S. Nat. Herb.); Hunting Creek, southwest of Alexandria, 11 August, 1902, *Shull 200, 201* (Mo. Bot. Gard. Herb. and U. S. Nat. Herb.); near Hunting Creek, southwest of Alexandria, in shallow

water, 11 August, 1902, *Shull 201* (Gray Herb.); so. margin Four Mile Run, 19 November, 1895, *Coville 123* (U. S. Nat. Herb.); tide beach in mud and gravel, mouth of Four Mile Run between Washington and Alexandria, 5 August, 1898, *Steele* (Mo. Bot. Gard. Herb. and U. S. Nat. Herb.); Four Mile Run, 4 mi. south of Washington, D. C., 22 August, 1902, *Shull 252* (Mo. Bot. Gard. Herb. and U. S. Nat. Herb.); Four Mile Run, near Alexandria, abundant between tidal limits, 12 July, 1905, *Ivar Tidestrom* (Gray Herb.); Hunting Creek, Alexandria, 13 August, 1910, *Dowell 6455* (U. S. Nat. Herb.).

48. I. riparia Engelm. A. Br. in Flora (Regensb. Bot. Zeit.) **29**: 178. 1846; Am. Jour. Arts and Sci. **3**: 52. 1847; Baker, Jour. Bot. **18**: 69. 1880; Motel. & Vendr. Actes Soc. Linn. Bord. **36**: 368. 1883; Engelm. Trans. St. Louis Acad. Sci. **4**: 382. 1884; Macoun, Cat. Canad. Pl. pt. 4: 293. 1888; Eaton in Gray, Manual, ed. 7, 60. 1908; Maxon in Britton and Brown, Ill. Fl., ed. 2, 52. 1913.

Calamaria riparia Kuntze, Rev. Gen. Pl. **2**: 828. 1891-93.

Corm 2-lobed; leaves 10–30, 9–30 cm. long, rather rigid, more slender than *I. lacustris,* deep green in color, with membranaceous margins but briefly extended; stomata numerous; peripheral strands lacking; ligule elongated, with narrow tip, ovate at base; sporangia spotted with brown cells, oblong, 4–7 mm. long, with narrow velum (covering sporangia 1/4–1/3); megaspores white, 440–660 μ in diameter, marked with conspicuous jagged crests, often with isolated peaks standing out sharply, sometimes anastomosing slightly; microspores cream-colored in mass, 25–33 μ long, tuberculate.

Distribution: southern Canada, New England, south to Delaware and Pennsylvania.

Specimens examined:

Canada: Crow River, northwest of Belleville, Hastings Co., 18 July, 1864, *Macoun* (Mo. Bot. Gard. Herb. and N. Y. Bot. Gard. Herb.).

Maine: Cornish, 1859, *Chickering 7* (Mo. Bot. Gard. Herb.).

Connecticut: Lantern Hill Pond, North Stonington, 23 July, 1901, *Graves & Bissell* (Mo. Bot. Gard. Herb.); Lantern Hill Pond, North Stonington, 23 July, 1901, *Bissell* (Gray

Herb.); abundant in mill-race and stiller waters of Mill River, near tide water, local, Fairfield, 5 September, 1897, *Eames* (Gray Herb.).

Vermont: in Connecticut River near Brattleborough, from foot deep to an inch or less (in fall when river recedes), on a pebbly bottom where the mud is deposited between the rocks, 1866, *Frost 6* (Mo. Bot. Gard. Herb.); Lake Bomoseen, W. Hubbardton, 3 October, 1897, *Eggleston 1786* (Gray Herb. and N. Y. Bot. Gard. Herb.); above low water line, region Lake Bomoseen, Castleton, 5 September, 1909, *Dutton 232* (Gray Herb.).

Massachusetts: Uxbridge, 1831, *Robbins 7* (Mo. Bot. Gard. Herb.); Uxbridge, 1843, *Robbins 8* (Mo. Bot. Gard. Herb.); Uxbridge, without date, *Robbins 9* (Mo. Bot. Gard. Herb.); Uxbridge, 1848, *Robbins 11* (Mo. Bot. Gard. Herb.); Uxbridge, 30 August, 1866, *Robbins 14* (Mo. Bot. Gard. Herb.); Uxbridge, in a mill pond, 1865, *Robbins* (Mo. Bot. Gard. Herb.); very shallow part of a cool pond (Capron's reservoir), 4 September, 1869, *Robbins* (N. Y. Bot. Gard. Herb.); small cold pond (Capron's fountain), 6 October, 1867, *Robbins* (N. Y. Bot. Gard. Herb.); Uxbridge, 1866, *Robbins* (N. Y. Bot. Gard. Herb.); some entirely submerged and some in mud on shore, South Natick, 25 June, 1879, *Morong* (N. Y. Bot. Gard. Herb.); ponds, Amherst, September, 1874, *Jesup* (Mo. Bot. Gard. Herb.); shallow water, So. Natick, September, 1878, *Morong* (Mo. Bot. Gard. Herb.); Taunton, Watson's Pond, 15 September, 1903, *Eaton* (Mo. Bot. Gard. Herb.); Uxbridge, 31 August, 1907, *Eaton* (Mo. Bot. Gard. Herb.); Shawshim River, Bedford, 25 August, 1884, *Jenks & Swan* (Mo. Bot. Gard. Herb. and Gray Herb.); Neponset River, Paul's Bridge, *Faxon* (Gray Herb.); Bedford, without date, *Swan* (Gray Herb.).

New Jersey: muddy banks of the Delaware River, Camden, September, 1860, *D. C. Eaton* (Mo. Bot. Gard. Herb.); along shores of the Passaic River, 6 mi. north of Newark, August, 1858, *Ennis* (Mo. Bot. Gard. Herb.); banks of the Delaware, above Camden, 1867 (?), *Durand* (Gray Herb.); shores of the Delaware, 22 September, 1866, *Parker* (Mo. Bot. Gard. Herb.); gravelly shore of the Delaware River, between high and low water mark, Camden, 20 September, 1867, *without*

collector (Mo. Bot. Gard. Herb.); margin of the Delaware, opposite Philadelphia, October, 1868, *ex. herb. Thurber* (Gray Herb.); shore of the Delaware, between high and low water mark, Camden, 7 October, 1877, *Parker* (Gray Herb.); Fish House, Delair, 19 August, 1906, *Poyser* (Mo. Bot. Gard. Herb.).

Delaware: shores of the Delaware River, 4 mi. above Wilmington, July, 1860, *Canby* (Mo. Bot. Gard. Herb.); shores of the Delaware, near low water mark, Newcastle Co., 1862, *Canby* (Mo. Bot. Gard. Herb.); shores of the Delaware River near Wilmington, 1865, *Canby* (Gray Herb.); Wilmington, 29 June, 1866, *Canby* (Gray Herb.); banks of the Delaware, between high and low water mark, 14 September, 1866, *Commons* (Mo. Bot. Gard. Herb.); Wilmington, 25 September, 1866, *Canby* (Gray Herb.); gravelly shores, Delaware River, between high and low water mark, near Wilmington, 11 July, 1866, *Commons* (Mo. Bot. Gard. Herb.); muddy shores of the Delaware River near Wilmington, August, 1867, *Canby* (Mo. Bot. Gard. Herb.); Wilmington, 12 June, 1867, *Canby* (Mo. Bot. Gard. Herb.); Wilmington, 1882, *Canby* (Mo. Bot. Gard. Herb.); river shore below Claymont, 22 June, 1896, *Commons* (Mo. Bot. Gard. Herb. and Gray Herb.); Delaware River, 1905, *Palmer* (Mo. Bot. Gard. Herb.).

Pennsylvania: inundated by tides, shores of Delaware River, Gibsonville (Philadelphia), 22 August, 1815, *Nuttall* (Mo. Bot. Gard. Herb.); Philadelphia, without date, *Eaton ex. herb. Thurber* (Gray Herb.); gravelly shore of the Delaware, near Philadelphia, August, 1844, *Zantziger* (Mo. Bot. Gard. Herb.), TYPE; Philadelphia, October, 1848, *Durand* (Mo. Bot. Gard. Herb.); banks of the Delaware, Philadelphia, July, 1860, *James* (Mo. Bot. Gard. Herb.); tidal mud, Tinicum to 11 mi. below Philadelphia, August, 1864, *Smith* (Mo. Bot. Gard. Herb.); banks of Delaware River near Philadelphia, 18 June, 1866, *Durand* (Mo. Bot. Gard. Herb. and Gray Herb.); Delaware River, August, 1894, *Palmer* (Mo. Bot. Gard. Herb.); banks of Lehigh River, on an island near Bethlehem, in sandy mud of river among and between stones, 1866, *Durand* (Mo. Bot. Gard. Herb. and Gray Herb.); along shaded bank of Lehigh River near Beth-

lehem, August, 1882, *Rau* (Mo. Bot. Gard. Herb.); gravelly banks, tidal margin of the Delaware, opposite Chester, August, 1894, *Palmer* (Mo. Bot. Gard. Herb.); shores of Delaware, opposite Chester, 22 August, 1896, *without collector* (U. S. Nat. Herb.); shores of Delaware, opposite Chester, 1 August, 1896, *Palmer* (Mo. Bot. Gard. Herb.).

48a. Var. **canadensis** Engelm. Trans. St. Louis Acad. Sci. 4: 383. 1884.

I. Dodgei Eaton, Fern Bull. **6**: 6. 1898.

I. Dodgei var. *Robbinsii* Eaton, Rhodora **10**: 42. 1908.

I. canadensis Eaton, Proc. U. S. Nat. Mus. **23**: 650. 1901; Bull. Torr. Bot. Club **30**: 359–362. 1903.

I. canadensis var. *Robbinsii* Eaton, Rhodora **5**: 7. 1903.

Usually larger than the species; leaves 15–75, 10–45 cm. long, with rather prominent membranaceous margins; stomata numerous; peripheral strands variable (2–4) or lacking; ligule cordate at base, subulate; sporangia 5–8 mm. long, partly covered by velum (¼–½); megaspores white, 440–650 μ in diameter, with usually scattered, thin, spiny crests, brief and discontinuous, though sometimes anastomosing, particularly on the basal face; microspores 27–37 μ long, minutely roughened to decidedly spinulose.

Distribution: eastern Canada, Massachusetts, Connecticut.

Specimens examined:

Canada: Petites Chaudiéres, near Ottawa, emersed, 11 August, 1917, *Bro. Rolland 6230* (Mo. Bot. Gard. Herb. and N. Y. Bot. Gard. Herb.); Brigham's Creek, Hull, 29 August, 1894, *Macoun 14213* (Gray Herb.); near Hull, 4 October, 1907, *Macoun 76921* (Gray Herb. and N. Y. Bot. Gard. Herb.); Ottawa River below railway bridge, Hull, 18 August, 1911, *Macoun 84084* (Gray Herb. and N. Y. Bot. Gard. Herb.); mud in places that had been overflowed in spring, Hull, October, 1890, *Macoun* (N. Y. Bot. Gard. Herb.).

New Hampshire: Kingston, 26 July, 1896, *Eaton 351* (Mo. Bot. Gard. Herb.); Kingston, 28 July, 1896, *Eaton 362* (Mo. Bot. Gard. Herb.); East Kingston, 9 September, 1897, *Eaton 900* (Mo. Bot. Gard. Herb.); flats of Powow River, Trickling Falls, Kingston, 28 July, 1896, *Eaton* (Mo. Bot. Gard.

Herb.); Kingston, September, 1897, *Eaton 942* (Mo. Bot. Gard. Herb.).

Massachusetts: Uxbridge, 1845, *Robbins 10* (Mo. Bot. Gard. Herb.); Watson's Pond, Taunton, 15 September, 1903, *Eaton* (Mo. Bot. Gard. Herb.); Leach's Pond (Wilbor's Pond), (Mass.?), September, 1906, *Eaton* (Mo. Bot. Gard. Herb.); Uxbridge, 31 August, 1907, *Eaton* (Mo. Bot. Gard. Herb.); rare, muddy shores, pool in Peabody Cemetery, 10 October, 1915, *Andrews* (Gray Herb.).

Connecticut: half submerged on shore of Chapman's Pond, Groton, 30 August, 1896, *Graves 144* (Mo. Bot. Gard. Herb.); mill-race in Mill River, Fairfield, 19 July, 1905, *Eames 5294* (Gray Herb.).

New Jersey: Pt. Pleasant, September, 1899, *Best* (Mo. Bot. Gard. Herb.); Pt. Pleasant, 4 July, 1899, *Best & Crawford* (Mo. Bot. Gard. Herb.).

The species and the variety are very close; the distinction is based chiefly on the tendency to larger size in the variety which is evinced in more and longer leaves. There is also an inclination toward larger microspores, though the ranges overlap sufficiently so that this too cannot be used absolutely. The Uxbridge material of Robbins is of the intermediate sort, with somewhat bigger microspores, but plant size according well with the general range of the species.

49. **I. Pringlei** Underw. Zoe 1: 98. 1890.

Corm 2-lobed; leaves 4–20, 16–30 cm. long, firm, fine, tapering, with membranaceous margin only briefly extended (1 cm.) above level of the sporangium; stomata abundant; peripheral strands numerous, 6 conspicuous and 6–10 accessory groups; ligule triangular, short and wide; sporangium large, up to 10–12 mm. in length in large individuals, partly covered by narrow velum; megaspores chalky white when dry, tan when moist, 460–550 μ in diameter, rarely 650 μ, marked with high tubercles, occasionally extended into brief rounded crests; commissural ridges irregular in outline; microspores fawn-colored, 35–42 μ long, sometimes showing tendency toward winged condition.

Distribution: Mexico.

Specimens examined:

Mexico: in grassy springy places near Guadalajara, State of

Jalisco, 1 November, 1890, *Pringle 3333* (Mo. Bot. Gard. Herb., Gray Herb., and U. S. Nat. Herb.).

50. I. Flettii Pfeiffer, comb. nov.

I. echinospora var. *Flettii* Eaton, Fern Bull. **11**:85. 1903. (name only); Eaton, Fern Bull. **13**: 51. 1905.

Corm 2-lobed; leaves 15–30, 5–8 cm. long, coarse, tapering, spreading or recurved, with wide basal sheath extending upward one-third of leaf length; stomata present; peripheral strands lacking; ligule blunt triangular; sporangia oblong, 4 mm. long, with velum developed less than half; megaspores 480–570 μ in diameter, marked with coarse low tubercles and short crests, usually somewhat distant; microspores 29–33 μ long, finely spinulose.

Distribution: Washington.

Specimens examined:

Washington: Spanaway Lake, Pierce Co., August, 1895, *Piper 2125* (Mo. Bot. Gard. Herb. and N. Y. Bot. Gard. Herb.); shore, Spanaway Lake, 17 September, 1899, *Allen* (N. Y. Bot. Gard. Herb.); amphibious, lake shore in gravel, Spanaway Lake, 7-8 October, 1899, *Flett 949* (Mo. Bot. Gard. Herb. and U. S. Nat. Herb.), TYPE; submerged, above in driest season, Spanaway Lake, 22 September, 1900, *Flett* (N. Y. Bot. Gard. Herb.); Spanaway Lake, under water, 20 May, 1911, *Bardell* (U. S. Nat. Herb.); Spanaway Lake, under water, 20 May, 1911, *Zeller* (U. S. Nat. Herb.).

51. I. lacustris L. Sp. Pl. 1100. 1753; Baker, Jour. Bot. **18**: 67. 1880, and Fern Allies, 125. 1887; Motel. & Vendr. Actes Soc. Linn. Bord. **36**: 325. 1883.

I. leiospora Klinggräff. Schr. Nat. Ges. Danzig **6**[1]: 20. 1884.

Calamaria lacustris Kuntze, Rev. Gen. Pl. **2**: 828. 1891-93.

Corm 2-lobed; leaves 8–40, 8–18 cm. in length, quadrangular in cross-section, erect, coarse, acutely pointed, dark green, with membranaceous border very wide at base, but not greatly prolonged beyond level of the sporangium; stomata and peripheral strands lacking; ligule usually short, triangular; sporangia 4–7 mm. long, with narrow velum; megaspores white, 500–700 μ in diameter, marked with numerous somewhat confluent, but little

anastomosing crests; commissural ridges irregular; microspores yellow-brown, 31–45 μ long, smooth.

Distribution: British Isles, north and central Europe.

Specimens examined:

British Isles:

Scotland: Loch Brandy, Clova, *Croall 1418* (Mo. Bot. Gard. Herb. and N. Y. Bot. Gard. Herb.); Loch Callater, Aberdeenshire, July, 1856, *Croall* (U. S. Nat. Herb.); Loch Cluny, Perthshire, September, 1850, *Walker-Arnott* (N. Y. Bot. Gard. Herb.); "Scotland," *Ward* (N. Y. Bot. Gard. Herb.); Loch Brandy, Forfarshire, August, 1837, *Brand* (*Soc. Bot. Edin. 183*) (N. Y. Bot. Gard. Herb.); Loch Brandy, Clova, August, 1837, *Balfour* (N. Y. Bot. Gard. Herb.); in a little lake near the Trossach's toward Callander, July, 1871, *without collector* (Gray Herb.); Loch Lomond, without date or collector (Gray Herb.).

Wales: Llanberis, 10 June, 1870, *Butter* (Mo. Bot. Gard. Herb.); Lake Llyn Padark, 20 August, 1862, *Gay* (Gray Herb.); Crôm y glo, North Wales, 12 November, 1862, *Gay* (?) (Mo. Bot. Gard. Herb. and Gray Herb.); Phrynon Vrech, 23 August, 1862, *without collector* (Mo. Bot. Gard. Herb.).

France: Lac de Gerardmer, Vosges, 16 July, 1858, *Cosson* (Mo. Bot. Gard. Herb.); Lac de Guéry, Puy-de-Dôme, 23-24 August, 1861, *Durieu* (Mo. Bot. Gard. Herb.); Lac de Guéry, 24 August, 1861, *Gay* (Gray Herb.); Lac de Guéry, Puy-de-Dôme, August, 1890, *Hy* (Mo. Bot. Gard. Herb.); Lac de Gerardmer, 15 October, 1856, *Jacquel* (Mo. Bot. Gard. Herb.); Lac de Guéry au Mont Dore, 16 August, 1877, *Allard* (U. S. Nat. Herb.); Lac de Gerardmer, near St. Dié, at bottom of water on granitic soil, 25 September, 1851, *Billot* (U. S. Nat. Herb.); in Lake Gerardmer, August, 1864, *Perrin* Gray Herb. and N. Y. Bot. Gard. Herb.); mountain lake, Chauvet, in Arvernia, 27 August, 1861, *Gay* (Gray Herb.); Lac de Bruyères, dans les Vosges, *Hornung* (N. Y. Bot. Gard. Herb.); Longemer, 2 July, 1881, *Study* (N. Y. Bot. Gard. Herb.); in bottom of Lakes Gerardmer, Longemer, and Retournemer, all the year (Stirp. Crypt. Vog.-Rhen., 1810-26), *Mougeot & Nestler 111* (N. Y. Bot. Gard. Herb.); lakes of the Vosges, 1833, *Mougeot* (N. Y. Bot. Gard. Herb.); in deep pools and ponds, through almost all the

year, *Desmazières 597* (N. Y. Bot. Gard. Herb.); lac de Guéry, near Mont Dore, Puy-de-Dôme, 14 September, 1879, *Heribaud* (N. Y. Bot. Gard. Herb.).

Spain: Lac de Bassibé, valley of the Rio Malo, Pyrenees Espagnoles, 11 August, 1880, *Lagrave* (N. Y. Bot. Gard. Herb.).

Norway and Sweden: lakes of Norway, *Blytt 1958* (Mo. Bot. Gard. Herb.); "N. Vi. s: N Vassviken vid Ribbingstrof," 11 August, 1870, (Ydre) *Dusen* (U. S. Nat. Herb.); "Vaerendia, Dref," August, 1879, *Hyltén-Cavallius 1771* (U. S. Nat. Herb.); "Augnil Hoysjs Mortsjord," July, 1887, *Franberg* (U. S. Nat. Herb.); Upland near Malaren, July, *Värnberg* (Mo. Bot. Gard. Herb. and Gray Herb.); "in Suecica", *Areschoug* (Gray Herb.); Uplandic, *Anderssen* (Mo. Bot. Gard. Herb.); "Smolandia Moheda," August, 1875, *Hyltén-Cavallius* (N. Y. Bot. Gard. Herb.); "Vedvson", July, 1868, *ex herb. Per Larson* (N. Y. Bot. Gard. Herb.); Smol. Moheda, lake, sand, August, 1881, *Hyltén-Cavallius* (N. Y. Bot. Gard. Herb.); near Stockholm, 1842, *Wicketson* (N. Y. Bot. Gard. Herb.).

Denmark: Madum Sö, 13 August, 1889, *Bergesen* (Mo. Bot. Gard. Herb.); Jutland, *Le Roy* (N. Y. Bot. Gard. Herb.); Landsee bei Espenkrug, *Klinsmann* (Mo. Bot. Gard. Herb.).

Germany: Grosser Teich (east side), Riesengebirge, August, 1866, *Engler* (N. Y. Bot. Gard. Herb.); Riesengebirge, August, 1866, *Ascherson* (Mo. Bot. Gard. Herb.); Titisee, Baden, August, 1846, *Braun* (Mo. Bot. Gard. Herb.); Titisee, May, 1846, *Braun* (Mo. Bot. Gard. Herb.); Titisee, July, 1864, *Braun* (Mo. Bot. Gard. Herb. and Gray Herb.); near Bütow, e. Pomerania, 1862, *Braun* (Mo. Bot. Gard. Herb.); near Heringsdorf, I. of Usedom, September, 1863, *Braun* (Mo. Bot. Gard. Herb.); in Lake Wjelling, near Bütow, 1867, *Doms* (Gray Herb.); Bütow, in Wjelling See, Pomerania, August, 1866, *Doms* (Mo. Bot. Gard. Herb.); Heringsdorf, Usedom, August, *Marrson 14* (Mo. Bot. Gard. Herb.); in Grosser Krebssee, near Heringsdorf, Usedom, September, 1864, *Braun* (Gray Herb.); Kleiner Krebssee, near Sallentin, I. of Usedom, September, 1864, *Braun* (Gray Herb., U. S. Nat. Herb., and N. Y. Bot. Gard. Herb.); Heringsdorf, in Kleiner Krebssee, 9 August, 1896, *Retter* (U. S. Nat. Herb.); Grosser

Krebssee, near Heringsdorf, I. of Usedom, 9 September, 1902, *without collector* (U. S. Nat. Herb.); "Feldsee bei Freiburg," 7 July, 1864, *Reess* (U. S. Nat. Herb.); Titisee near Freiburg, 1866, *Magnus* (U. S. Nat. Herb.); Titisee, Schwarzwald, 187-, *Reinsch* (U. S. Nat. Herb.); Feldbergsee, Schwarzwald, 30 June, 1868, *Zickendrath* (N. Y. Bot. Gard. Herb.); on stony bottom of Feldsee, Feldberg, Schwarzwald, 17 July, 1834, *Meisner* (N. Y. Bot. Gard. Herb.); Einfelder See, Lauenburg, Schleswig-Holstein, *Nolte 1601* (N. Y. Bot. Gard. Herb.); Titisee, 1000 m., September, 1885, *Christ* (N. Y. Bot. Gard. Herb.); 20–50 cm. below water surface, stony substratum, in Steinsee near Kirchseeon, upper Bavaria, July, 1900-01, and July & August, 1902, *Hepp 599* (Gray Herb.); in lake, Gardsee, Ratzeburg, September, 1864, *Reinke* (Gray Herb.); Grosser Teich, Riesengebirge, Silesia, July, 1866, *Milde* (Gray Herb.); Grosser Teich, Riesengebirge, 31 July, 1874, *Buchenau* (Gray Herb.); Wiggoda in Moritzsee, West Prussia, 10 May, 1885, *Lützow* (Gray Herb.); Gr. Ottalsiner See, West Prussia, 10 August, 1885, *Lützow* (Gray Herb.); Schluchsee in Black Forest, September, 1867, *without collector* (Gray Herb.); Riesengebirge, 24 August, 1884, *Hieronymus* (Mo. Bot. Gard. Herb.); near Danzig, W. Prussia, 1854, *Klebsman* (Mo. Bot. Gard. Herb.); millpond, "Lohmülle", near Lockstedter Lager, Holstein, August, 1886, *without collector* (Mo. Bot. Gard. Herb.).

Bohemia: Bistritzer See, near Eisenstein, *Celakovsky 1503* (U. S. Nat. Herb. and Gray Herb.).

Austria: "Grosser Teich," Sudetic Mts., *Milde* (Mo. Bot. Gard. Herb.).

Finland: Northern Lavonia, Kvopio, 26 July, 1901, *Budden* (U. S. Nat. Herb.); region of Abo "par. Lojo" in lacu Hormasjo, 6 September, 1893, *Boldt 17* (Mo. Bot. Gard. Herb.); same station, 27 August, 1909, *Boldt 418* (Mo. Bot. Gard. Herb.).

Russia: St. Petersburg, "Hellgründiger See in Lewaschweo," 2–19 August, 1898, *Poring* (U. S. Nat. Herb.).

52. I. occidentalis Hend. Bull. Torr. Bot. Club **27**: 358. 1900.

I. lacustris var. *paupercula* Engelm. Trans. St. Louis Acad. Sci. **4**: 377. 1882.

I. paupercula (Engelm.) Eaton. Proc. U. S. Nat. Mus. **23**: 649. 1901, and in Gilbert, List N. Am. Pterid. **10**: 28. 1901.

Corm 2-lobed; leaves commonly 9–30, rarely 60, 5–20 cm. long, dark green, rigid, gradually tapering, with wide membranaceous border at base, extending 2–3 times length of sporangium above level of latter; peripheral strands and stomata lacking; ligule short-triangular; sporangia almost orbicular, 5–6 mm. long, with narrow velum (covering about 1/3 of sporangium); megaspores cream-colored, 525–640 μ in diameter, marked with low conspicuous irregular crests, chiefly simple on the apical faces, branching to form irregular network on basal face; microspores 24–42 μ long, spinulose.

Distribution: Idaho, Wyoming, Colorado, California.

Specimens examined:

Idaho: in water from 6 in. to 6 ft. deep, Lake Coeur d'Alene, 22 August, 1897, *Henderson 2979* (Mo. Bot. Gard. Herb.); in 2 ft. of water, Lake Coeur d'Alene, August, 1898, *Henderson* (Mo. Bot. Gard. Herb.); in 2 ft. of water, Lake Coeur d'Alene, August-September, 1897, *Henderson 4786* (Gray Herb.).

Wyoming: Yellowstone Park, 1885, *Tweedy 416* (U. S. Nat. Herb. and Gray Herb.); growing in deep water at north end of Yellowstone Lake, 16 August, 1900, *Bessey 1* (N. Y. Bot. Gard. Herb.).

Colorado: "covering the bottom of Grand Lake in granitic sand, 3–4 ft. under the surface of water, abundant, meadow-like, Middle Park," 5 August, 1881, *Engelmann* (Mo. Bot. Gard. Herb.).

California: Donner Lake, September, 1887, *Curran* (Mo. Bot. Gard. Herb. and N. Y. Bot. Gard. Herb.); Donner Lake, *Shockley* (Mo. Bot. Gard. Herb.); Castle Lake, mountains about the headwaters of the Sacramento River, alt. 6000 ft., 14 August, 1881, *Pringle* (Mo. Bot. Gard. Herb. and Gray Herb.).

53. I. Piperi Eaton, Fern Bull. **13**: 51. 1905; name only in Fern Bull. **11**: 85. 1903; Piper, Contr. U. S. Nat. Herb. **11**: 89. 1906.

I. occidentalis var. *Piperi* (Eaton) Nelson & MacBride, Bot. Gaz. **61**: 30. 1916.

Corm 2-lobed; leaves 8–26, 3–10 cm., rarely 15 cm., long, medium fine, erect or somewhat spreading, taper-pointed, broadly winged for twice length of sporangium; peripheral strands and stomata lacking; ligule short, triangular, ovate; sporangia 4–5 mm. long, with variation in width of velum from 1/3 to 2/3 of sporangium; megaspores white, 540–800 μ in diameter, marked with points or tubercles and short ridges, sometimes slightly serpentine; microspores 29–35 μ, rarely 42 μ, long, papillose.

Distribution: Washington.

Specimens examined:

Washington: Seattle, 11 July, 1889, *Piper* (Mo. Bot. Gard. Herb.); Seattle, 11 July, 1889, *Smith* (Mo. Bot. Gard. Herb.); Lake Washington, near Seattle, 11 July, 1889, *Piper & Smith 651* (N. Y. Bot. Gard. Herb.); Green Lake, King Co., 12 July, 1895, *Piper 2317* (Mo. Bot. Gard. Herb. and N. Y. Bot. Gard. Herb.), TYPE; mostly submerged in clear lake, Five Mile Lake, Tacoma, 3 October, 1902, *Flett 2034* (Mo. Bot. Gard. Herb., U. S. Nat. Herb., and N. Y. Bot. Gard. Herb.); Lake Washington, Seattle, August, 1907, *Piper & Hungate* (U. S. Nat. Herb.); submerged, Lake Crescent, 20 August, 1911, *Webster* (U. S. Nat. Herb.); in Green Lake, near Seattle, June, 1891, *Piper 1102* (N. Y. Bot. Gard. Herb.).

It is possible that *I. Piperi* Eaton and *I. occidentalis* Hend. may be more closely related than as adjacent species. A slight difference in habit of the leaves (more gradual tapering in *I. occidentalis*, coupled with greater length), a difference in spore sizes, with *I. Piperi* tending to show the larger megaspores and smaller microspores, and a simpler form of sculpture on *I. Piperi* compared with the anastomosing ridges of *I. occidentalis*, and a tendency toward wider velum in *I. Piperi*, serve to distinguish these two submerged species.

SECT. 4. RETICULATAE

§ 4. RETICULATAE. Forms with 2-3 lobed corms; producing megaspores evidently reticulate, at least on basal face; microspores smooth or rough.

Key to Species

A. Corms 2-lobed.
  a. Submersed forms, stomata none or rare.
    α. Megaspores chiefly 600–800 μ in diameter.
      I. Spore markings irregular, sharp crests ..... *54. I. macrospora*
      II. Spore markings prominent, rounded ridges ..... *54a. I. macrospora* f. *hieroglyphica*
    β. Megaspores chiefly 460–600 μ in diameter ..... *55. I. Tuckermani*
  b. Amphibious forms, stomata at least near leaf tips.
    α. Leaves less than 18 cm. long ..... *56. I. foveolata*
    β. Leaves chiefly more than 18 cm. long.
      I. Megaspores large, over 580 μ in diameter ..... *57. I. Martii*
      II. Megaspores usually less than 580 μ in diameter.
        1. Spore surface reticulate with narrow ridges, 400–570 μ in diameter.
          *Velum narrow, covering less than ⅓ of sporangium ..... *58. I. Engelmanni*
          **Velum covering ⅓–⅔ of sporangium ..... *58a. I. Engelmanni* var. *caroliniana*
        2. Spore surface reticulate with rounded ridges, 360–490 μ in diameter ..... *59. I. azorica*
B. Corms 3-lobed.
  a. Aquatic, lacking velum.
    α. Peripheral strands present ..... *60. I. japonica*
    β Peripheral strands lacking ..... *61. I. Wormaldii*
  b. Terrestrial, with complete velum ..... *62. I. Duriaei*

54. I. macrospora Dur. Bull. Soc. Bot. Fr. **11**: 101. 1864; Clute, Fern Allies, 224. 1905; Eaton in Gray, Manual, ed. 7, 58. 1908; Maxon in Britton & Brown, Ill. Fl., ed. 2, **1**: 50. 1913.

I. lacustris Engelm. Trans. St. Louis Acad. Sci. **4**: 377. 1882; Motel. & Vendr. Actes Soc. Linn. Bord. **36**: 325. 1883; Baker, Jour. Bot. **18**: 67. 1880.

I. Harveyi Eaton, Fernwort Papers, 11. 1900.

I. Tuckermani var. *Harveyi* Clute, Fern Allies, 226. 1905.

I. heterospora Eaton, Fernwort Papers, 8. 1900.

I. macrospora var. *heterospora* Eaton, Rhodora **10**: 42. 1908.

I. Tuckermani heterospora Clute, Fern Allies, 227, 260. 1905.

Corm 2-lobed; leaves usually 13–40, occasionally more numerous, 5–22 cm. in length, rigid, slightly to decidedly coarse, abruptly tapering to apex; peripheral strands lacking; stomata absent or very rare; ligule short triangular; sporangia 3–5 mm. long, with narrow velum; megaspores white, 600 (550)–800 μ, or more in rare cases, with sculpture of irregular ridges more or less parallel, with little confluence on upper faces, anastomosing, sometimes with clear reticulations on the lower face; microspores 33–45 (50) μ long, short spinulose.

Distribution: Newfoundland west to Minnesota.

Specimens examined:

Newfoundland: in shallow water of sandy pond, Torbay, 1901, *Howe & Lang 1424* (N. Y. Bot. Gard. Herb. and Gray Herb.); Whitbourne, 8 August, 1911, *Fernald & Wiegand 4409* (Gray Herb.).

Quebec: in 2–6 dm. water, rooting in close-packed granite gravel, Lac des Americains, alt. 675 m., western base of Table-Top, Mt. Gaspé, 1–2 August, 1906, *Fernald & Collins 155* (Mo. Bot. Gard. Herb., Gray Herb., and Univ. Minn. Herb.); alpine lakes, alt. 900–1000 m., Lac Fortin, Table-Top, Mt. Gaspé Co., 10 August, 1906, *Fernald & Collins 319* (Gray Herb.); Lac 43, Mt. Gaspé Co., 4 August, 1906, *Fernald & Collins 317* (Gray Herb.).

Nova Scotia: in shallow water, sandy soil, lake, North Sydney, Cape Breton, 1901, *Howe & Lang 763* (N. Y. Bot. Gard. Herb.); Warren Lake, Cape Breton Isl., 15 August, 1914, *Nichols 877* (Gray Herb.); cobbly margins of east branch of Tusket River, Gavelton, Yarmouth Co., 4 September, 1920, *Fernald, Long & Linder 19625* (Mo. Bot. Gard. Herb).

Maine: brook flowing into north end of Jordan's Pond, Mt. Desert I., 22 July, 1889, *Redfield 2726* (Mo. Bot. Gard. Herb.); under water, Somes Stream, Mt. Desert I., 27 July, 1892, *Rand* (Mo. Bot. Gard. Herb.); Deer Brook Beach, Jordan Pond, 23 August, 1892, *Rand* (Mo. Bot. Gard. Herb.); south shore of Jordan Pond, 10 September, 1894, *Rand 3* (Mo. Bot. Gard. Herb.); in shallow water where a cold spring enters the pond, Northwest Pond, north Franklin Co., 14 July, 1895, *Coville 83* (N. Y. Bot. Gard. Herb. and U. S. Nat. Herb.); in 2 ft. water, gravelly bottom, Kennebago Lake, 5 mi. north of Rangeley, 12 July, 1895, *Coville 78* (N. Y. Bot. Gard. Herb. and U. S. Nat. Herb.); Penobscot River, Orono, September, 1895, *F. L. Harvey 1* (N. Y. Bot. Gard. Herb.); Bubble Pond, Mt. Desert I., 11 September, 1895, *Rand 2* (Mo. Bot. Gard. Herb.); Pushaw Pond, Oldtown, August, 1895, *Harvey 2* (N. Y. Bot. Gard. Herb.); Pushaw Pond, 21 August, 1899, *F. L. Harvey* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.); Pushaw Pond, Oldtown, 21 August, 1899, *L. H. Harvey 1411* (U. S. Nat. Herb.); rocky shore, "Lake Cowles," Mt. Ktaadn, 15–30 August, 1902, *Cowles & Harvey*

1 (Mo. Bot. Gard. Herb.); Lower Basin Pond, Mt. Ktaadn, 15–30 August, 1902, *Harvey 3* (Mo. Bot. Gard. Herb.); growing in 18 in. water at unusually low stage of water, Pushaw Pond, Orono, 17 September, 1905, *Knight 14* (Mo. Bot. Gard. Herb. and Gray Herb.).

New Hampshire: Echo Lake, Franconia Mt., 17 September. 1856, *Engelmann* (Mo. Bot. Gard. Herb.).

Vermont: near old mill, east shore and Long Cove, Willoughby Lake, 3, 5, 7 August, 1907, *Winslow* (Mo. Bot. Gard. Herb.); Willoughby, 2 September, 1900, *Lovery* (Gray Herb.); shore of Silver Lake, Leicester, 10 July, 1910, *Dutton 787* (Mo. Bot. Gard. Herb.).

Massachusetts: Fresh Pond, north side, 20 August, 1867, *Boott 11* (Mo. Bot. Gard. Herb.); same station and date, without number (Gray Herb.); same station, 12 August, 1868, *Boott* (N. Y. Bot. Gard. Herb.); Uxbridge, without date, *Robbins 1* (N. Y. Bot. Gard. Herb.).

New York: Catskill Mts., *Schweinitz* (Mo. Bot. Gard. Herb.), probably TYPE; Third Lake, Fulton Chain, September, 1899, *Underwood* (N. Y. Bot. Gard. Herb.); Clear Lake, south of Elk Lake, Adirondacks, 4 September, 1894, *Britton* (N. Y. Bot. Gard. Herb.).

Michigan: small lake near Douglas Lake, Cheboygan Co., August, 1918, *Praeger* (Mo. Bot. Gard. Herb.); Isle Royale, 6 August, 1901, *Cooper 26* (Gray Herb.); in 1–2 ft. water, Vincent Lake, Cheboygan Co., 15 August, 1917, *Ehlers 621* (Gray Herb.); Vincent Lake, 30 July, 1918, *Ehlers 817* (Mo. Bot. Gard. Herb.).

Minnesota: Devils Track Lake, Cook Co., 28 August, 1901, *Lyon* (Mo. Bot. Gard. Herb.).

54a. Forma **hieroglyphica** Pfeiffer, comb. nov.

I. hieroglyphica Eaton, Fernwort Papers, 10. 1900.

Habit of the species; megaspores 560–720 μ in diameter, rarely less, marked with prominent rounded or smooth ridges, slightly reticulate on upper faces, decidedly so on lower, sometimes naked near commissural ridges; microspores as in species.

Specimens examined:

Maine: St. Francis Lakes between Maine and Canada, 31 July, 1880, *Pringle* (Mo. Bot. Gard. Herb., U. S. Nat. Herb., Gray

Herb., and N. Y. Bot. Gard. Herb.), TYPE; in 4 ft. of water off the dock, Maneskootuk, Rangeley Lake, 7 July, 1895, *Coville 62* (U. S. Nat. Herb. and N. Y. Bot. Gard. Herb.); Moosehead Lake, September, 1899, *F. L. Harvey 4* (Mo. Bot. Gard. Herb.).

55. I. Tuckermani A. Br. acc. Engelm. in Gray, Manual, ed. 5, 676. 1867; Engelm. Trans. St. Louis Acad. Sci. 4: 378. 1882; Motel. & Vendr. Actes Linn. Soc. Bord. 36: 338. 1883; Baker, Jour. Bot. 18: 68. 1880, and Fern Allies, 126. 1887; Underwood, Native Ferns and Fern Allies, 122. 1882; Macoun, Cat. Canad. Pl. pt. 4: 293. 1888; Eaton in Gray, Manual, ed. 7, 59. 1908; Britton & Brown, Ill. Fl., ed. 2, 1: 51. 1913; Clute, Fern Allies, 225. 1905.

I. Tuckermani var. *borealis* Eaton, Fernwort Papers, 10. 1900.

Calamaria Tuckermani Kuntze, Rev. Gen. Pl. 2: 828. 1891-93.

Corm 2-lobed, rarely 3; leaves 5–38, 3–18 cm. long, very slender, tapering, olive-green, outer leaves frequently recurved; stomata lacking or few in number; peripheral strands none; sporangia orbicular to oblong, 2–5 mm. long, often brown-spotted; velum incomplete, covering about 1/3 of sporangium; megaspores white, 460–600 μ, rarely 650 μ, in diameter, with upper segments marked with somewhat parallel and branching thin ridges, chiefly irregular at margins, lower segment with reticulate ridges; microspores 26–34 μ, rarely more (40) in length, smooth to minutely papillose.

Distribution: Labrador, Newfoundland, Quebec, Nova Scotia. Maine, New Hampshire, Vermont, Massachusetts, Connecticut.

Specimens examined:

Labrador: pond, Triangular Harbor, 23 August, 1882, *Allen* (Mo. Bot. Gard. Herb.).

Newfoundland: in 3–6 in. water, Quiddy Viddy Lake, *Robinson & Schrenk 239* (Mo. Bot. Gard. Herb., U. S. Nat. Herb., N. Y. Bot. Gard. Herb., Univ. Minn. Herb., and Gray Herb.).

Quebec: on firm clay bottom, small ponds among Silurian hills back of Birchy Cove (Curling), 11 August, 1910, *Fernald & Wiegand 2404* (Gray Herb.); emersed, muddy border of a shallow brook, Lewisport, south shores of Notre Dame Bay, 17 August, 1911, *Fernald & Wiegand 4402* (Gray Herb.).

Nova Scotia: in Pleasant Lake, Springfield, 16 August, 1910, *Macoun 81092* (Gray Herb.); pond, North Sydney, Cape Breton Isl., 14 July, 1883, *Macoun 14223* (in part) (Gray Herb. and N. Y. Bot. Gard. Herb.); Boylston, August, 1890, *Hamilton 81051* (in part) (Gray Herb.); in a brook, Bridgewater, 28 July, 1910, *J. Macoun 81091* (Gray Herb.); shallow water of Midway (Centreville) Lake, Centreville, Digby Co., 22 August, 1920, *Graves & Linder 19621* (Mo. Bot. Gard. Herb.); quiet pools in Little River and pond holes in savannahs east of Tidville, Digby Co., 22 August, 1920, *Fernald & Long 19620* (Mo. Bot. Gard. Herb.); shallow water at sandy margin of Great Pubnico Lake, Yarmouth Co., 6 September, 1920, *Fernald, Long & Linder 19627* (Mo. Bot. Gard. Herb.); peaty margin of Kegeshook Lake, Yarmouth Co., 8 October, 1920, *Fernald & Linder 19630* (Mo. Bot. Gard. Herb.); peaty and muddy, dried-out pond-hole near the head of St. John Lake, Springhaven, Yarmouth Co., 8 October, 1920, *Fernald & Linder 19631* (Mo. Bot. Gard. Herb.); shallow water of Everitt Lake, 10 August, 1921, *Fernald & Long 23109* (Mo. Bot. Gard. Herb.).

Maine: Mt. Desert, 23 July, 1871, *Boott* (N. Y. Bot. Gard. Herb.); Mt. Desert I., Somes Stream, 4 Sept., 1895, *E. & C. E. Faxon* (Gray Herb.); Pushaw Pond, 21 August, 1899, *F. L. Harvey 3* (Mo. Bot. Gard. Herb.); Ripples Brook, under water, Somesville, 1 August, 1892, *Rand* (Gray Herb.); brook, north end of Dunning's Pond, Somesville, 27 August, 1869, *Boott* (N. Y. Bot. Gard. Herb.); Ripple Brook, Somesville, Mt. Desert I., 1 August, 1892, 3 October, 1893, *Rand* (Mo. Bot. Gard. Herb.); Somes Stream, Mt. Desert I., 30 September, 1893, *Rand* (N. Y. Bot. Gard. Herb.); same station, 4 September, 1895, *Rand* (Mo. Bot. Gard. Herb.); west shore of Jordan's Pond, Mt. Desert I., 3 September, 1892, *Rand* (Mo. Bot. Gard. Herb.); Small Pond, north of Long Pond and Ripples Brook, and north end of Great Pond, "Northwest Arm," 22 September, 1892, *Fernald* (Gray Herb.); brook, south end of Ripple Pond, Mt. Desert I., 3 October, 1893, *Rand* (Mo. Bot. Gard. Herb. and N. Y. Bot. Gard. Herb.); at dam, Ripples Pond, in gravel mud, Mt. Desert I., 19 September, 1898, *Rand* (Mo. Bot. Gard. Herb. and Gray Herb.); in brook, inlet of Ripples Pond,

19 September, 1898, *Rand* (Gray Herb.); in clay mud, south end Great Pond, Mt. Desert I., 19 September, 1898, *Rand* (Mo. Bot. Gard. Herb.); west shore of Jordan Pond, Mt. Desert I., in sand under water, 3 September, 1892, *Rand* (Mo. Bot. Gard. Herb.); pond north of Long Pond, Mt. Desert I., 22 September, 1892, *Fernald* (Gray Herb.); Ripples Pond, 22 September, 1892, *Fernald* (N. Y. Bot. Gard. Herb.); rocky bed of Great Works River, North Berwick, York Co., 25 September, 1897, *Fernald* (Gray Herb.); Bubble Pond, Mt. Desert I., 11 September, 1895, *Rand* (Mo. Bot. Gard. Herb.); same, 18 September, 1898, *Rand* (Mo. Bot. Gard. Herb.); ledgy margin of Stillwater River, Orono, 4 September, 1893, *Fernald y* (Gray Herb. and N. Y. Bot. Gard. Herb.); submersed, at end Eagle Lake, Mt. Desert I., 20 September, 1900, *Rand* (Gray Herb.); Harrison, Cumberland Co., 31 July, 1919, *Eames & Godfrey 9604* (Gray Herb.); York, August, 1893, *Thaxter* (Gray Herb.); gravelly margin of Pease River, East Wilton, 11 August, 1894, *Fernald* (Gray Herb.); mill stream, Somesville, 10 July, 1893, *Rand & Redfield 3121* (Mo. Bot. Gard. Herb.).

New Hampshire: Echo Lake, N. Conway, 8 June, 1879, *Faxon* (Mo. Bot. Gard. Herb. and Gray Herb.); sandy bottom of ponds, Kingston, August, 1895, *Eaton* (N. Y. Bot. Gard. Herb.); country pond, Newton, 18 August, 1896, *Eaton 440* (Mo. Bot. Gard. Herb.); millpond, Lamprey R., West Epping, 20 August, 1896, *Eaton* (U. S. Nat. Herb. and Univ. Minn. Herb.); country pond, Kingston, 5 August, 1896, *Dodge* (N. Y. Bot. Gard. Herb.); bed of Lamprey R., Epping, 16 September, 1896, *Eaton* (Mo. Bot. Gard. Herb.); West Epping, 20 August, 1896, *Eaton 482C* (Mo. Bot. Gard. Herb.); Gustin Pond, Marlow, 29 July, 1899, *Fernald 186* (in part) (Gray Herb.); Pautuckaway Pond, Nottingham, *Eaton 483B* (Mo. Bot. Gard. Herb. and N. Y. Bot. Gard. Herb.); same locality, 20 August, 1896, *Eaton* (Univ. Minn. Herb.); Epping, 12 August, 1896, *Eaton 424, 431* (Mo. Bot. Gard. Herb.); Epping Corner, *Eaton* (Mo. Bot. Gard. Herb.); Gould Pond, Greenfield, in about 3 ft. water, among yellow lilies, mud over granite gravel, 24 July, 1906, *Coville 2219* (Mo. Bot. Gard. Herb. and U. S. Nat. Herb.); country pond, Kingston,

September, 1895, *Eaton* (Univ. Minn. Herb.); Lake Chocorua, 10 September, 1906, *Farlow* (Gray Herb.); Lamprey River at Hedding, in about 10 in. water, 8 August, 1904, *Bragg* (N. Y. Bot. Gard. Herb.).

Vermont: Grout Pond, Stratton, alt. 2225 ft., 6–10 August, 1900, *Eggleston 2200* (Mo. Bot. Gard. Herb., N. Y. Bot. Gard. Herb., and Gray Herb.); South Pond, Marlboro, 15 September, 1895, *Grout & Eggleston* (N. Y. Bot. Gard. Herb.); sandy shore of Kelly's Bay, Alburgh, 31 August, 1893, *Eggleston* (N. Y. Bot. Gard. Herb.); Lamprey R., Epping, 16 September, 1899, *Eaton* (Univ. Minn. Herb.).

Massachusetts: in the Mystic, not the Pond, Medford, August, 1848, *Tuckerman* (Gray Herb.), TYPE; submersed at margin of winter pond, Winchester, 22 September, 1908, *Fernald* (Gray Herb.); Arlington, 15 September, 1867, *Boott* (Gray Herb.); Martin's Pond, Reading, 24 August, 1869, *Boott* (N. Y. Bot. Gard. Herb.); Pinkapog Pond, 27 August, 1867, *Boott* (N. Y. Bot. Gard. Herb.); submerged, Worcester, *Stone* (N. Y. Bot. Gard. Herb.); Horn Pond, south end, 16 September, 1869, *Boott* (N. Y. Bot. Gard. Herb.); Kimball's Pond, Amesbury, 15 August, 1899, *Eaton* (Univ. Minn. Herb.); Mystic Pond, 6 August, 1865, *Boott* (Mo. Bot. Gard. Herb. and Gray Herb.); Mystic River near Boston, from issue from Mystic Pond to Wood's Dam, 21 October, 1866, *Boott* (Mo. Bot. Gard. Herb. and Gray Herb.); east side of Mystic Pond, 14 July, 1867, *Boott* (Mo. Bot. Gard. Herb. and Gray Herb.); north and west side of Mystic Pond, 9 August, 28 October, 1867, *Boott* (Mo. Bot. Gard. Herb. and Gray Herb.); north and east sides of Spy Pond, Arlington, 5–8 September, 1867, *Boott* (Mo. Bot. Gard. Herb. and Gray Herb.); Fresh Pond, north side, 3 September, 1868, *Boott* (Gray Herb.); entirely submerged, Spy Pond, Arlington, August, 1878, *Morong* (Mo. Bot. Gard. Herb., N. Y. Bot. Gard. Herb., and U. S. Nat. Herb.); Nutting Pond, Billerica, 11 August, 1869, *Boott* (N. Y. Bot. Gard. Herb.); entirely submerged, Horn Pond, 29 October, 1866, *Boott* (Mo. Bot. Gard. Herb. and Gray Herb.); Spy Pond, Arlington, 8 August, 1881, *Morong* (N. Y. Bot. Gard. Herb.); lower end of Horn Pond, 30 June, 1867, *Boott*

(Gray Herb.); Horn Pond, 11 July, 16 September, 1867, *Boott* (Mo. Bot. Gard. Herb. and Gray Herb.); Waushakum Pond, So. Framingham, 29 June, 20 July, 1890, *Sturtevant* (Mo. Bot. Gard. Herb.); sandy bottom, Lake Attitash, Amesbury, August, September, 1895, *Eaton* (Mo. Bot. Gard. Herb., U. S. Nat. Herb., and Univ. Minn. Herb.); Quannaponit Lake, Wakefield, 10 September, 1869, *Boott* (N. Y. Bot. Gard. Herb.); Attitash, Essex Co., *Eaton 960* (Mo. Bot. Gard. Herb.); same, 27 June, 1896, *Eaton 197* (Mo. Bot. Gard. Herb.); same, 31 July, 1896, *Eaton 382* (Mo. Bot. Gard. Herb.); Chebacco Pond, Essex Co., 15 July, 1896, *Dodge* (N. Y. Bot. Gard. Herb.); Chebacco Lake, Essex Co., August, 1896, *Eaton* (Mo. Bot. Gard. Herb. and Univ. Minn. Herb.); same, without date, *Eaton 378* (Mo. Bot. Gard. Herb.); Chebacco Lake, Essex Co., 18 July, 1896, *Dodge* (Gray Herb.); Bate's Pond, Wenham, 29 July, 1896, *Eaton 376* (Mo. Bot. Gard. Herb.); Nine-Mile Pond, Cape Cod, 4 September, 1898, *Greenman 424* (Mo. Bot. Gard. Herb.); Watson's Pond, Taunton, 15 September, 1903, *Eaton* (Mo. Bot. Gard. Herb.); Winneconnet Pond, Norton, 14 July, 1903, *Eaton* (Mo. Bot. Gard. Herb.); Merrimac River, Newburyport, August, 1896, *Dodge* (N. Y. Bot. Gard. Herb.); in fresh water, tidal shores Merrimac R., Newburyport, 1896, *Eaton* (Mo. Bot. Gard. Herb.); Kimball's Pond, Amesbury, July, 1896, and August, 1897, *Eaton* (Mo. Bot. Gard. Herb.); Kimball's Pond, Amesbury, 27 June, 1896, *Eaton* (Univ. Minn. Herb.); Kimball's Pond, Essex Co., 13 August, 1899, *Eaton* (Mo. Bot. Gard. Herb.); near Jerry's Pond, West Tisbury, Martha's Vineyard, 24 August, 1916, *Seymour 1017* (Gray Herb.); Lake Cochichewick, North Andover, 24 September, 1903, *Pease 2640* (Gray Herb.); submerged in shallow water, sandy margin of Great Pond, Weymouth, Norfolk Co., 2 September, 1918, *Churchill* (Mo. Bot. Gard. Herb.); carpeting the sandy bottom of Spectacle Pond, Wellfleet, Barnstable Co., 19 September, 1918, *Fernald & Weatherby 15950* (Gray Herb. and Mo. Bot. Gard. Herb.); sandy bottom, Great Pond, Weymouth, 2 September, 1918, *Knowlton* (Mo. Bot. Gard. Herb. and Gray Herb.); Buck Pond, Harwich, wet sandy lower beach and inundated margin, 30 August,

1918, *Fernald & Long 15949* (Gray Herb. and Mo. Bot. Gard. Herb.).

Connecticut: muddy border of pond, Niantic, East Lyme, 19 August, 1913, *Bissell* (Gray Herb.); submerged, stony shore, lower end of Long Pond, Ledyard, 4 August, 1896, *Graves 139 & 140* (Mo. Bot. Gard. Herb.); same place and date, *Graves* (Gray Herb.); in mud, bare at low water, head of Hamburg Cove, Lyme, 10 September, 1902, *Graves* (Mo. Bot. Gard. Herb.).

56. I. foveolata Eaton in Dodge, Ferns and Fern Allies of N. Eng. 38. 1896.

Corm 2-lobed, rarely 3; leaves 20–45, 8–18 cm. long, rather slender, round, becoming dark green; stomata few, near tips of leaves; peripheral strands none; ligule short triangular; sporangia 4–7 mm. long, brown-spotted, with very narrow velum; megaspores white, 360–560 μ, rarely 600 μ, in diameter, densely sculptured with somewhat irregular reticulations formed by wide, high ridges surrounding deep pits; microspores 23–33 μ long, minutely papillose.

Distribution: New Hampshire.

Specimens examined:

New Hampshire: pond on Lamprey River, Epping, 20 August, 1896, *Eaton* (Mo. Bot. Gard. Herb. and Gray Herb.), TYPE; West Epping, 20 August, 1896, *Eaton 482A* (Mo. Bot. Gard. Herb. and Gray Herb.); Epping Corner, 14 September, 1899, *Eaton 299* (Mo. Bot. Gard. Herb.); New Market, *Eaton* (Mo. Bot. Gard. Herb.); Epping, Pautuckaway River, *Eaton 432* (Mo. Bot. Gard. Herb.); Lamprey River, Epping, August, 1897, *Eaton* (Mo. Bot. Gard. Herb.).

57. I. Martii A. Br. Kuhn in Martius, Fl. Brasil. 1^2: 646. *pl. 78.* 1884; Baker, Fern Allies, 129. 1887.

Corm 2-lobed, small; leaves 24–52, up to 75 cm. in length, soft green, flexuous, reddish brown at base, with membranaceous margins extending 6–8 cm. above sporangium level; stomata near tips of leaves, lacking below; peripheral strands usually lacking or weak; ligule cordate-triangular; sporangium 6–8 mm. long, partly covered by velum (1/2–2/3); megaspores chalky white, 580–660 μ in diameter, marked with irregular, confluent,

high, blade-like ridges, extending away from commissural ridges on upper faces, somewhat incompletely reticulate above, irregularly reticulate basally; microspores fawn-colored, 30–35 μ long, smooth.

Distribution: Brazil.

Specimens examined:

Brazil: Prov. Minas Geraës, 22 January, 1874, 18 December, 1864, *Regnell ser. III 1506* (Gray Herb. and U. S. Nat. Herb.), TYPE; Serra do Itatiaia, " in rivulo," 29 June, 1902, *Dusen 643* (U. S. Nat. Herb.).

58. **I. Engelmanni** A. Br. Flora **29**. 178. 1846; Baker, Jour. Bot. 18: 105. 1880; Motel. & Vendr. Actes Linn. Soc. Bord. **36**: 374. *pl. 12. fig. 1–9.* 1883; Gray, Manual, ed. 4, 606. 1869; Clute, Fern Allies, 233. 1905.

I. Engelmanni var. *gracilis* Engelm. in Gray, Manual, ed. 5, 677. 1867.

I. Engelmanni var. *fontana* Eaton, Fern Bull. **13**: 52. 1905.

I. Engelmanni var. *valida* Engelm. in Gray, Manual, ed. 5, 677. 1867.

I. valida Clute, Fern Allies, 236, 260. 1905.

Corm 2-lobed; leaves 15–60 (100), 13–50 cm. long, light green; stomata numerous; peripheral strands variable in number or none; sporangia oblong, unspotted, with narrow velum; megaspores white, 400–570 (615) μ in diameter, distinctly marked with honeycomb network of narrow ridges; microspores 21–30 μ, seldom 33 μ, in length, smooth to minutely roughened.

Distribution: eastern border to Mississippi Valley.

Specimens examined:

New Hampshire: "In a slight brooklet, dry most of the summer," in a forest, Seabrook, July, 1895, *Eaton* (Mo. Bot. Gard. Herb.); millpond, in clay, Hampton Falls, August, 1895, *Eaton* (Mo. Bot. Gard. Herb.); Coffin's Mill, 16 July, 1896, *Eaton* (Mo. Bot. Gard. Herb.); mill-pond, Hampton Falls, 1 August, 1896, *Eaton* (Mo. Bot. Gard. Herb.); Powow River, South Hampton, 18 August, 1896, *Eaton 439* (Mo. Bot. Gard. Herb.); Trickling Falls, 1896, *Eaton* (Mo. Bot. Gard. Herb.); East Kingston, 28 July, 1896, *Eaton 363–364* (Mo. Bot. Gard. Herb.); flats at East Kingston, 6 July, 1896, *Eaton 231* (Mo.

Bot. Gard. Herb.); flats at Trickling Falls, Kingston, August, 1897, *Eaton* (Mo. Bot. Gard. Herb.); Dodge's Pond, Hampton Falls, *Eaton* (Mo. Bot. Gard. Herb.); Horse Hill, Kensington, 19 April, 1896, *Eaton 1* (Mo. Bot. Gard. Herb.); Lamprey River, Epping, August, 1897, *Eaton* (Mo. Bot. Gard. Herb.); Stratham, 1899, *Eaton* (Mo. Bot. Gard. Herb.).

Vermont: in Clark's Pond, near Brattleborough, " in spring submerged, in fall on dry banks," 1867, *Mann* (Mo. Bot. Gard. Herb.); Brattleborough, 1867, *Frost 18* (Gray Herb.); in shallow water on muddy bottom, Little Pond, Orwell, 8 August, 1915, *Eames & Godfrey 9204a* (Gray Herb.).

Massachusetts: Woburn Brook, 16 November, 1862, *Boott* (Mo. Bot. Gard. Herb.); millpond stream in West Cambridge, 26 October & 5 November, 1865, *Boott* (Mo. Bot. Gard. Herb.); West Cambridge, entirely out of water, 26 October, 1865, *Boott* (Gray Herb.); West Cambridge Brook, entirely submerged (5 miles northwest from Boston), 29 October, 1866, *Boott* (Mo. Bot. Gard. Herb.); Arlington Brook, 23 October, 1867, *Boott* (Mo. Bot. Gard. Herb.); Arlington Brook, 12 September, 1867, *Boott* (Mo. Bot. Gard. Herb.); Arlington Brook, 7 August, 1870, *Boott* (Gray Herb.); South Natick, 25 June, 1879, *Morong* (Mo. Bot. Gard. Herb. and Gray Herb.); in water and mud along margin where pond has dried away, Blacksmith Pond, Needham, 19 July, 1885, *Fuller* (Gray Herb.); near dam, Waverley, November, 1894, *Duggar* (Gray Herb.); mill-pond, Waverley, October, 1894, *Seymour* (Gray Herb.); Newburyport, 22 June, 1894, *Dodge* (Mo. Bot. Gard. Herb.); West Newbury, July, 1896, *Dodge* (Mo. Bot. Gard. Herb.); Tuxbury's Pond, *Eaton* (Mo. Bot. Gard. Herb.); Waverley, 11 October, 1894, *Blankinship* (Mo. Bot. Gard. Herb.); Blue Hills Reservation, Metropolitan Park System, 2 September, 1895, *Jenks* (Mo. Bot. Gard. Herb.); Pine Tree Pool, Blue Hills Reservation, 2 September, 1895, *Williams* (Gray Herb.); in brook, Blue Hills, Quincy, 5 September, 1895, *Fernald* (Gray Herb.); Shaker Glen, Woburn, 1 September, 1895, *Williams* (Gray Herb.); Race Course Pond, Billingham, 24 August, 1894, *E. & C. E. Faxon* (Gray Herb.); Nashawena Island, Buzzards Bay, *C. E. Faxon 7* (Mo. Bot. Gard. Herb. and Gray

Herb.); in shallow water, Blue Hills Reservation, West Quincy, 2 September, 1895, *Rich* (Gray Herb.); pool, heart of Pine-Tree Brook, Blue Hills Reservation, Milton, 2 September, 1895, *Churchill* (Gray Herb.).

Rhode Island: Newport, July, 1878, *C. E. Faxon 5* (Mo. Bot. Gard. Herb. and Gray Herb.); near Newport, in deep water, 1866, *Durand* (Mo. Bot. Gard. Herb.); shallow pool, Newport, 1878, *Farlow* (Mo. Bot. Gard. Herb,); (Wordens Pond) "Lake Werden," So. Kingston, 24 August, 1881, *E. & C. E. Faxon* (Gray Herb.); Newport, *Thurber* (Gray Herb.).

Connecticut: fresh water, tidal shores, New Haven, 1857, *D. C. Eaton 1* (Mo. Bot. Gard. Herb.); without date, New Haven, *D. C. Eaton* (Gray Herb.); shallow mountain stream on gravelly bottom, Colebrooks, 10 September, 1864, *Robbins 13* (Mo. Bot. Gard. Herb.); edge of little pond in Meriden, pond south of West Peak, 10 October, 1873, *Hall* (Mo. Bot. Gard. Herb.); Bristol, 1888, *Bishop* (U. S. Nat. Herb.); Hart's Upper Reservoir, Berlin, 27 September, 1900, *Bishop* (Gray Herb.); shallow water, Eight-Mile River "at railroad," Southington, 3 August, 1902, *Bissell* (Mo. Bot. Gard. Herb.); submerged in shallow water of Mill River, Easton, 29 August, 1897, *Eames* (Gray Herb.); shallow water of pond, in mud, Stafford, 28 August, 1903, *Bissell* (Mo. Bot. Gard. Herb.); pond at Stafford St., Stafford, 28 August, 1903, *Bissell* (Gray Herb.); Bantam Lake, July, 1891, *Underwood* (Gray Herb.); Rainbow Park, Windsor, 30 August, 1907, *Eaton* (Mo. Bot. Gard. Herb.); Selden's Cove, Lyme, 28 August, 1907, *Eaton* (Mo. Bot. Gard. Herb.); "Curtis' Mill-Pond," Stepney, 11 September, 1897, *Eames* (Gray Herb.); pond at icehouse, Norwalk, 16 September, 1901, *Bissell* (Gray Herb.); in shallow water, Waterbury, 7 July, 1908, *Blewitt* (Gray Herb.); New Britain, 22 June, 1913, *Lunt* (Gray Herb.); small pond at foot of West Peak, Meriden, 25 September, 1910, *Bissell* (Gray Herb.); wet bank of pond, Gaylordsville, 29 August, 1904, *Eames* (Gray Herb.); Miamus River, Stamford, 5 July, 1909, *Eames* & *Godfrey 8223* (Gray Herb.); abundant in Bunnell's Pond, in 1–3 ft. water, Bridgeport, 5 August, 1913, *Eames* (Gray Herb.); in half-shade, shallow water of pond, southeastern

part of town of Sterling, 12 August, 1914, *Bissell* (Gray Herb.).

New York: high water mark, muddy shores just above Peekskill, 19 August and 3 September, 1869, *Leggett?* (Gray Herb.); Peekskill, Hudson River, high water mark, 3 September, 1869, *Leggett* (Mo. Bot. Gard. Herb.); Locke Pond, Central New York, 21 July, 1881, *Dudley* (Mo. Bot. Gard. Herb.); marl ponds, South Cortland, 29 June, 1884, *Dudley* (Mo. Bot. Gard. Herb.); east side, Cayuta Lake, in sand, 21 June, 1885, *Dudley A* (Mo. Bot. Gard. Herb.); marl pond near South Cortland, 3 August, 1886, *Dudley* (Mo. Bot. Gard. Herb.); near Norwich, Chenango Co., 21 August, 1888, *Fitch* (Mo. Bot. Gard. Herb.); near Ithaca, 1898, *Overacker* (Mo. Bot. Gard. Herb.); Ithaca, July, 1898, *Ashe* (Mo. Bot. Gard. Herb.); Mt. Vernon, 28 October, 1900, *Clute* (Mo. Bot. Gard. Herb.); brook at East Chester, 28 October, 1900, *Buchheister* (Mo. Bot. Gard. Herb.); pond, McLean, 19 July, 1916, *Munz 479* (Pomona Coll. Herb.); muddy border of Isoetes Pond, South Cortland, 18 July, 1915, *Faull 3430* (Gray Herb.); in 3 ft. of water near south end of Lake Ronkonkoma, Suffolk Co., 5 July, 1908, *Harper 38* (Gray Herb.); mudhole southwest of Chicago bog, Cortland, 22 July, 1916, *McDaniels 5446* (Mo. Bot. Gard. Herb.); Sparta, 16 August, 1907, *von Schrenk* $\frac{250}{07}$ (Mo. Bot. Gard. Herb.); in dried pond, Chicago Station, Ithaca, 6 August, 1921, *Drushel 4664* (Mo. Bot. Gard. Herb.).

New Jersey: near Camden, opposite Philadelphia, September, 1863, *Durand* (Mo. Bot. Gard. Herb.); "mud and spring water", 5½ miles from Philadelphia in N. J., 1 October, 1865, *Smith* (Mo. Bot. Gard. Herb.); in a ditch on the Atlantic City Railroad, 4 miles from Camden, 1866, *Durand* (Mo. Bot. Gard. Herb.); pool 3½ miles from Camden, on railroad to Atlantic City, end of October, 1867, *Durand* (Mo. Bot. Gard. Herb.); Closter, 1859, *Austin 3* (Mo. Bot. Gard. Herb.); bottom of Hackensack River, without date, *Austin* (U. S. Nat. Herb.); submerged, sandy bottom, Panther Pond, Sussex Co., 18 September, 1904, *Mackenzie 1059* (Mo. Bot. Gard. Herb.).

Pennsylvania: West Chester, 1839, *McMinn* (U. S. Nat. Herb.); Lancaster Co., *Porter* (Gray Herb.); swamp at Smithville

near Lancaster, in soft mud, half immersed, 1 October, 1866, *Porter* (Mo. Bot. Gard. Herb.); in small ditches, not near tide-water, near Darby, Philadelphia, 4 July, 1866, *Hunt* (Mo. Bot. Gard. Herb.); Delaware Water Gap, June–July, 1870, *Knipe* (Mo. Bot. Gard. Herb.); mountain swamp, 2 miles southwest of Cornwall, Lebanon Co., 1 August, 1878, *Porter* (Mo. Bot. Gard. Herb.); wholly immersed in a lake at Delaware Water Gap, August, 1880, *Canby* (Mo. Bot. Gard. Herb.); Delaware River, at Monroe, Buck Co., 24 July, 1886, *J. A. & H. F. Ruth* (Univ. Minn. Herb.); Monroe Co., 26 July, 1886, *Porter* (Dudley Herb.); McCall's Ferry, 2 miles south of Bethesda, July, 1898, *Galen* (Mo. Bot. Gard. Herb.); Susquehanna River, Wayne Co., 20 July, 1900, *Clute* (Mo. Bot. Gard. Herb.); pool among rocks, York Co., 2–6 July, 1904, *Britton* (Mo. Bot. Gard. Herb. and N. Y. Bot. Gard. Herb.); Sayre, edge of river, August, *Barbour* (Mo. Bot. Gard. Herb.); Delaware Water Gap, 3 July, 1887, *Britton* (Gray Herb.); vicinity of McCall's Ferry, York Co., 5–7 July, 1904, *Rose & Painter 8168, 8216* (U. S. Nat. Herb.); in soft mud of a partially exsiccated pond, near Warriorsmark, Huntingdon Co., at foot of Alleghenies, 20 August, 1868, *Porter* (Mo. Bot. Gard. Herb. and Gray Herb.); in clay mud and water of a pond in the barrens of Huntingdon Co., 1200 ft. above sea-level, September, 1870, *Porter* (Mo. Bot. Gard. Herb. and Gray Herb.); Smithville, Lancaster Co., August, 1865, *Porter* (Mo. Bot. Gard. Herb.); same, 1 October, 1866, (Mo. Bot. Gard. Herb.); pond near Warriorsmark, October, 1870, *Davis* (Mo. Bot. Gard. Herb.).

Delaware: Wilmington, 1860, *Tatnall* (Gray Herb.); in a bog near Wilmington, 1858, *Tatnall* (Gray Herb.); Wilmington, 16 June & 23 July, 1866, *Canby* (Mo. Bot. Gard. Herb. and Gray Herb.); in a ditch near Ogletown (dry at time of collection), 4 August, 1866, *Commons* (Mo. Bot. Gard. Herb.); ponds, Townsend, 4 July, 1896, *Canby* (Mo. Bot. Gard. Herb.); in small ditch along Baltimore River, ⅛ mile below Stanton Station south of Wilmington, 21 September, 1866, *Canby* (Mo. Bot. Gard. Herb.); same, August, 1867, (Mo. Bot. Gard. Herb.); Wilmington, 1865, *Durand* (Mo. Bot. Gard. Herb.); Wilmington, 25 September, 1866, *Canby* (Mo. Bot. Gard. Herb. and Gray Herb.); Wilmington, ditch-

es near Baltimore R. R., 16 June, 1866, *Canby* (Mo. Bot. Gard. Herb.); Wilmington, 23 July, 1866, *Canby* (Mo. Bot. Gard. Herb.); same, 21 September, 1866, & 12 June, 1867, *Canby* (Mo. Bot. Gard. Herb. and Gray Herb.); Wilmington, 2 October, 1866, *Canby* (Gray Herb.); ditches near Stanton, August, 1867, *Canby* (Mo. Bot. Gard. Herb.); Delaware, June, 1872, *Canby* (Gray Herb.); Stanton, June, 1872, *Canby* (Gray Herb.); near Wilmington, *Canby 1957* (Mo. Bot. Gard. Herb.).

Maryland: near Great Falls of the Potomac, 11 June, 1882, *Ward* (Mo. Bot. Gard. Herb.).

Virginia: head of Mountain Lake, Salt Pond Mt., alt. 4000 ft., August, 1889, *Canby* (Mo. Bot. Gard. Herb.); swampy soil near Mountain Lake, Salt Pond Mt., August, 1869, *Canby* (Gray Herb.).

North Carolina: in standing water, Swain Co., 10 August, 1891, *Beardslee & Kofoid* (Mo. Bot. Gard. Herb. and Gray Herb.); near Hendersonville, May, 1919, *Thomas* (Mo. Bot. Gard. Herb.); in bogs formed by cold springs on Spring Mts. (near Columbus), Polk Co., elev. about 3000 ft., 5 May, 1897, *Biltmore Herb. 55641* (Gray Herb.).

South Carolina: springy places near Graniteville, Aiken Co., 19 May, 1899, *Eggert* (Mo. Bot. Gard. Herb.); same station, 24 & 25 May, *Eggert* (Mo. Bot. Gard. Herb.).

Georgia: mountains of Georgia, 1872, *Chapman* (N. Y. Bot. Gard. Herb.); mountain streams of Georgia, 1873, *Chapman* (Mo. Bot. Gard. Herb.); Floy Co., *Chapman* (Mo. Bot. Gard. Herb.); wet shady woods at eastern base of Taylor's Ridge, Whitfield Co., 26 July, 1900, *Harper 310* (Mo. Bot. Gard. Herb., N. Y. Bot. Gard. Herb., and Gray Herb.).

Indiana: in a small pond, 8.7 miles southeast of Paoli, on Paoli and New Albany Pike, 16 October, 1917, *Deam 24360* (Mo. Bot. Gard. Herb.); in small pond on north side of road and about 1 mi. east of Pilot Knob, Crawford Co., 12 October, 1916, *Deam 22385* (Gray Herb.); low place in woods, where in wet seasons the water would course through woods, 4 mi. south and 1 mi. east of Palmyra, Harrison Co., *Deam 20467* (Gray Herb.).

Illinois: Ponds, St. Clair Co., *Eggert* (Mo. Bot. Gard. Herb.).

Missouri: ponds in the Meramec Hills, southwest of St. Louis (Gravois Settlement), September, 1842, *Engelmann* (Mo. Bot. Gard. Herb. and Gray Herb.), TYPE; St. Louis, September, 1842, *Engelmann* (U. S. Nat. Herb.).

58a. Var. caroliniana Eaton, Fern Bull. 8: 60. 1900.

Corm 2-lobed; leaves 15–25(30), up to 22 cm. long, little finer than *I. Engelmanni* (much like *I. Dodgei*); peripheral strands 4, weak; stomata numerous; sporangium 6–8 mm. long, 1/3–2/3 covered by velum; megaspores 400–530 μ in diameter, with high reticulate ridges, much crisped and cut with an irregular margin, producing somewhat spiny effect; microspores 24–34 μ long, spinulose.

Distribution: North Carolina, Georgia.

Specimens examined:

North Carolina: Big Rock Creek, Mitchell Co., 1893, *Ashe 1092* (Mo. Bot. Gard. Herb.), TYPE; growing partly immersed, Wetherby's near Salisbury, Mitchell Co., *Ashe 812* (Mo. Bot. Gard. Herb.); Roandale Farm, 28 July, 1900, *Wetherby* (Mo. Bot. Gard. Herb.); edge of fish-pond, gravelly bottom, half submerged or less, Wetherby's, 15 August, 1898, *Wetherby* (Mo. Bot. Gard. Herb.).

Georgia: muddy swamp of Turkey Creek, about 6 mi. south of Dublin, Laurens Co., 21 April, 1904, *Harper 2142* (U. S. Nat. Herb.); in sluggish pine-barren stream, Sumter Co., partly emersed, 24 July, 1901, *Harper 1112* (Mo. Bot. Gard. Herb. and U. S. Nat. Herb.).

59. I. azorica Dur. Milde, Fil. Eur. 278. 1867; Baker, Jour. Bot. **18**: 67. 1880, and Fern Allies, 125. 1887; Motel. & Vendr. Actes Soc. Linn. Bord. **36**: 365. *pl. 8. fig. 9, 10, 11.* 1883; Trelease, Mo. Bot. Gard. Ann. Rept. 8: 176 . 1897.

Calamaria azorica Kuntze, Rev. Gen. Pl. 2: 828. 1891-93.

Corm 2-lobed; leaves 7–25, 8–30 cm. long, slender, flexuous, with narrow basal membranaceous margin; stomata present, but not numerous; peripheral strands none; ligule long subulate; sporangia oval, 4–6 mm. long, 1/3–1/2 covered by velum; megaspores 360–490 μ in diameter, white, reticulate with narrow low distinct crests, mostly rounded, seldom sharp; microspores

brown, 26–37 μ in length, chiefly spinulose, sometimes smoothish.

Distribution: Islands of Azores.

Specimens examined:

Azores: Lago Raza, 4 August, 1894, *Trelease 1262* (Mo. Bot. Gard. Herb.); Corvo Caldeiro, 15 July, 1894, *Trelease 1261* (Mo. Bot. Gard. Herb. and U. S. Nat. Herb.); Flores I., Caldeiro da Lomba, 25 July, 1894, *Trelease 1263* (Gray Herb., Mo. Bot. Gard. Herb. and U. S. Nat. Herb.).

60. I. japonica A. Br. Verh. Bot. Ver. Brandenb. **4**: 329. 1862, and Monatsber. K. Akad. Wiss. Berlin **1**: 459. 1861; Motel. & Vendr. Actes Soc. Linn. Bord. **36**: 360. *pl. 11. fig. 10-12.* 1883; Baker, Jour. Bot. **18**: 109. 1880, and Fern Allies, 133. 1887; Miquel, Prol. Fl. Jap. 390. 1866-67; Franchet & Sav. Enum. Pl. Jap. **2**: 201. 1879.

Calamaria japonica Kuntze, Rev. Gen. Pl. 2: 828. 1891-93.

I. edulis Lieb. ex Miq. Prol. Fl. Jap. 390. 1866-67.

Corm 3-lobed; leaves 35–66, 33–52 cm. long, medium coarse, flexuous, gradually tapering to apex, with membranaceous margin conspicuous only at sporangium level; peripheral strands usually 6, 4 of which are stronger; stomata rare; ligule elongated triangular; sporangia 7–9 mm. long, lacking velum, but marked with brown sclerenchyma patches; megaspores white, 560–660 μ in diameter, with large foveolate markings, slightly less regular on apical faces, with well-rounded ridges on basal; microspores pale, 29–35 μ long, smooth.

Distribution: Japan, Yokohama.

Specimens examined:

Japan: Wada-mura, Musashi, 6 September, 1893 (U. S. Nat. Herb.); Tokyo, May, 1888, *collector unknown, 519* (U. S. Nat. Herb.); 30 July, 1890, *Watanabe* (Gray Herb.).

61. I. Wormaldii Sim, Trans. S. Afr. Phil. Soc. **16**[3]: 299. *pl. 5.* 1906, and Ferns of S. Afr. 340. 1915.

Corm 3-lobed; leaves 50–70 in number, terete or somewhat flattened, 22–45 cm. long, stout, hardly narrowed to the rounded point, flaccid, with wide basal sheath briefly extended (2–3 cm.); peripheral strands none; stomata present though not numerous; sporangium large, 5–10 mm. long, 3–3.5 mm. wide, lacking a velum; megaspores 460–640 μ in diameter, with surface decidedly reticulate with prominent rounded ridges on lower

surface, sometimes little sharper above; microspores 28–35 μ in length, tuberculate.

Distribution: East London, S. Africa.

Specimens examined:

South Africa: East London, Lake Province, Union of S. Africa, November, 1921, *Schonland* (Mo. Bot. Gard. Herb.).

In the description published by Sim, mention is made of peripheral strands as being "one marginal on each side throughout." The material at hand in the single collection examined did not show peripheral strands in any sections cut. In all the leaves the basal portion was the chief region available, though some of the narrower part was cut in a few sections. It may be that with exposure near the water surface there is some development of supporting tissue not witnessed in Schonland's collection.

62. I. Duriaei Bory, Compt. Rend. Acad. Paris 18: 1166. 1844.

I. tridentata Dur. acc. Kuhn, Fil. Afr. 195. 1867.

I. ligustica de Not. acc. Kuhn, Fil. Afr. 195. 1867.

Isoetella Duriaei Genn. Comment. Critt. Ital. (1) no. 2: 115. 1861.

Calamaria Duriaei Kuntze, Rev. Gen. Pl. 2: 828. 1891-93.

Corm 3-lobed; leaves 15–35, 8–12 cm. long, rarely longer, slender, firm, recurved, with short wide membranaceous margins at base; bases of leaves persistent, scaly, shining black, with 3 teeth; stomata numerous; peripheral strands 4; sporangia oval, 4–6 mm. long, with complete velum; megaspores white, 600–830 μ in diameter, with prominent commissural ridges, and faces with reticulate markings produced by even, rounded elevations; microspores 26–38 μ in length, tuberculate.

Distribution: Algeria, Corsica, France, Italy, Turkey.

Specimens examined:

Algeria: Algeria, 1841, *Durieu* (Mo. Bot. Gard. Herb.); Bebazoun near Algiers, March, 1844, *Durieu* (Mo. Bot. Gard. Herb.); dry sandy plateaus of Mastapha near Algiers, 7 June, 1863, *Durieu* (Mo. Bot. Gard. Herb.).

Sicily: Pantelleria, Favare, April, 1890, *Rose* (N. Y. Bot. Gard. Herb.); in wet fields, Messina, June, 1907, *Ross 800* (Gray Herb.).

Corsica: pastures, Bastia, 15 March, 1865, *Debeaux* (Mo. Bot. Gard. Herb.); in swampy places, near Bastia, Corsica,

March, 1869, *Gandoger* (Mo. Bot. Gard. Herb.); wet grasslands at edge of water, at "Griggione," near Bastia, 25 April, 1869, *Fl. Exsicc. Billot 2290* (Mo. Bot. Gard. Herb.); Erisa, March, 1885, *Reverchon* (Mo. Bot. Gard. Herb.).

France: Plateau de Roquehaute (Hérault), 3–5 June, 1862, *Durieu* (Gray Herb.); Roquehaute near Béziers (Hérault), 3 June, 1862, *Cosson* (Mo. Bot. Gard. Herb. and Gray Herb.); Roquehaute near Béziers, 5 May, 1866, *Herb. Grand Marais* (Mo. Bot. Gard. Herb.); Portiragnes (Hérault), 30 March, 1890, *Neyraut* (Mo. Bot. Gard. Herb.); Hérault, 1870 (?), *Durieu* (Gray Herb.); sandy clearings of pine between Cannes and Antibes, 1861, *Bourgeau, Pl. Alpes maritimes, (Gay) 361* (Gray Herb.); near Cannes, 13 June, 1861, *Bourgeau 2* (Gray Herb.); "bois de la Moure prés Montpellier", 8 May, 1870, *Duval-Jouve* (Gray Herb.); Antibes, November, 1863, *Kay* (Gray Herb.); wet sandy stretches under the pines, Golfe Jouan, near Antibes, *Shuttleworth* (Gray Herb.).

Italy: Asciano, Prov. Pisa, Tuscany, alt. 12 m., calcareous soil, 14 April, 1906, *Barsali 401* (Gray Herb.); province Pisa, April, 1862, *Ball* (Gray Herb.).

Turkey: Rizeh, Lazistan, arid land at base of Falaises, 10 June, 1866, *Balansa 1560* (Gray Herb.).

Sardinia: St. Barbara near Cagliari, 19 May, 1863, *Ascherson & Reinhardt* (Gray Herb.).

LITTLE-KNOWN FORMS

63. I. natalensis Baker, Handbook Fern Allies, 132. 1887. Sim, Ferns S. Afr. 340. 1915.

"Rootstock 3-lobed; leaves 12–16, very slender (¼ lin. diam.), pale green, opaque, firm in texture, 2–3 inches long, rounded on the back, channeled down the face, furnished with stomata and accessory bast-bundles. Sporange small, globose, brownish; *veil none*. Macrospores white, with small tubercles between the ribs and large ones over the remainder of the surface. Microspores granulated."

Distribution: "Natal; Griffin's Hill, Eastcourt, Rehmann. 7296."

Specimens examined:

Africa: Cape of Good Hope, *Lehman* (Gray Herb. and Mo. Bot. Gard. Herb.).

Gray Herb. collections shows megaspores 570–600 μ in diameter, minutely roughened on the three upper faces, and on the fourth, showing short serpentine ridges. The vegetative characters coincide well with Baker's form; the number of leaves is 11, they are fine and long (31–32 cm.), and bear oblong sporangia (3–5 mm. long), with *no* velum.

It seems as if Rehmann might conceivably be a misprint of Lehman.

Mo. Bot. Gard. Herb. specimen has 10 very slender leaves, 30–35 cm. long, with fairly prominent basal sheath; spores of same character as above but as low as 480 μ; velum very narrow.

64. **I. neoguineensis** Baker in Sadebeck, Engl. and Prantl, Nat. Pflanzenfam. 1^4: 776. 1901.

Placed with *I. Mulleri* A. Br. and *I. Kirkii* A. Br., under division with indusium complete, with more or less numerous stomata; megaspores gray or light gray, warty.

List of Exsiccatae Cited

The distribution numbers are printed in italic. Collections distributed without numbers are indicated by a dash. The numbers in parentheses indicate the species numbers in the present revision.

Allard — (51).
Allen — (42); — (50); — (55).
Anderssen — (40).
Andrews — (48a).
Archer — (23).
Areschoug — (51).
Arrhenius — (40).
Arthur, Bailey, Holway *B413, B87* (42).
Arsene *3653* (37).
Ashe *1092, 812,* — (58a).
Ascherson — (7); — (16); — (51); — (62).
Ascherson & Reinhardt — (16); — (25a); — (62).
Austin *3* (58).
Balansa *1560* (62); *1327* (25a); *849* (25); — (10).
Balfour — (51).
Ball — (25); — (62).
Ballard — (6).
Barber *394* (42).
Barbour — (58).
Bardell — (50).
Barsali *401* (62).
Battey — (42).
Beardslee & Kofoid — (58).
Bergesen — (51).
Bessey *1* (52); *2* (35).
Best — (48a).
Best & Crawford — (48a).
Billot — (51); *2290* (62).
Biltmore Herb. *4264, 4264b* (29); *55641* (58).
Bishop — (42); — (58); — (42a).

Bissell — (42); — (55); — (58); — (42a); — (48).
Blanchard — (42).
Blankinship — (58).
Blasdale — (26).
Blewitt — (58).
Blomberg — (40).
Blytt *1951* (40); *1958* (51).
Bolander — , *5093, 5091, 5080* (35); *6025, 6383* (35a).
Boldt *17, 418* (51).
Bootт — (42); — ,*11* (54); — (55); — (58).
Boreau — (12).
Bory —(25); — (10); — (15a).
Bourlier — (15).
Bourgeau — *2, 361* (62).
Bragg — (55).
Brainerd — (42).
Brand — (51).
Brandegee — (26); — (34); *674* (34a); — (27); — , *2001* (35).
Braun — (40); — (51).
Bristol — (42).
Britton, Dr. & Mrs. — (42).
Britton — (42); — (46); — (54); — (58).
Brown — (42).
Bubani — (6).
Buchenau — (51).
Buchheister — (58).
Budden — (51).
Burbank, Grout & Eggleston — (42).
Burtt Davy — (27).
Bush — ,*441, 746, 267, 35, 107, 1531,* (38); *1530, 107, 231, 68, 7547, 2917, 4511* (39).
Butler — (38); — ,*24* (39).
Butter — (51).
Canby — (29); *136* (39); — (42); — (47); — (48); *1957*, — (58).
Carnel — (25).
Celakovsky *1503* (51).
Cesati — (7); — (40).
Chaboisseau *395, 70* (12).
Chamberlain — (42).
Chapman — (31); — (42); — (58).
Chase *86, 136* (38).
Cheeseman — ,*56* (17); — (18).
Cheveneau — (6).
Chickering *7* (48).
Chiovenda — (40).
Christ — (40); — (51).
Churchill — (42); — (55); — (58).
Clauson *99, 99bis* (15).
Clemens *1, 2* (35).
Clements, R. E. & E. S. *493.1* (42).
Clinton — (42).
Clokey *3986* (35).
Clute — (42); — (58).
Collins — (42).
Commons — (48); — (58); — (47).
Congdon *91* (34); *991* (35).
Cooper *26* (54).
Copeland *3281* (34).
Cosson — (6); — (15); — (15a); — (15b); — (25); — (40); — (51); — (62).
Coville *2483, 1053* (35); *84* (42); *123* (47); *83, 78,* (54); *62* (54a); *2219* (55).
Coville & Funston *1722, 1643, 1650, 1691* (35).
Coville & Kearney *2336, 2337, 386* (43).
Coville & Leiberg *271* (35).
Cowles *776* (42).
Cowles & Harvey *2* (42); — ,*1* (54).
Croall —, *1418* (51).
Curran — (34); — (26); — (27); — (35); — (52).
Curtiss *3813* (31); *3813, 6696* (31a).
Cusick *1451* (35).
Darlington — (42).
Davenport — (42).
Davis — (42); — (58).
Deam *24360, 20467, 22385* (58).
de Bary —(40).
Debeaux — (15); — (15a); — (25); — (62).
de Gerard — (6).
de la Perraudiere — (6).
Delile — (6).
Deloynes — (12).
Dement — (38).
Desmazières *597* (51).
de Vichet — (6).
Dodge — (42); — (46); — (55); — (58).
Doms — (12); — (51).
Dorfler *3698* (6).
Dowell *6435* (47).
Drushel *4664* (58).
Dudley *1043* (34); — (58).
Duggar — (58).
Durand — (48); — (58).
Durieu *21* (6); — (11); — (10); — (15a); — (25); *781* (25a); — (40); — (51); — (62).
Duscu — (40).
Dusen — (51).
Dutton *397, 198, 260* (42); *232* (48); *787* (54).
Duval-Jouve — (62); — (6).
Eames *9671* (42a); — (48); *5294* (48a); — (58).
Eames & Godfrey *9604* (55); *8223, 9204a* (58).
Eames, Metcalf & Wiegand *5445* (42).
Eastwood — (34); — (26).
Eaton, *ex herb. E.* (29); *337, 1244, 1455, 832* (31a); *ex herb. E.* (11);

441, 187, 699, 431, 425a, 482b, 483a, 364, 239, 197, 380, 192, 919, 377, 441, 913 (42); *351,163, 589, 898, 482c, 427, 217, 919* (46); — (48); *351, 362, 900, 942* (48a); *440, 482C, 483B, 424, 431, 960, 197, 382, 378, 376* (55); *482A, 299, 432* (56); *439, 363, 364, 231, 1* (58).

Eaton — (48); *1* (58).

Eggert — (29); — (38); — (39); — (58).

Eggleston *3026, 1785, 2201, 2472, 699* (42); *1786* (48); *2200* (55).

Ehlers *621, 817* (54).

Engelmann —, *1954* (29); — (35); — (42); — (52); — (54); — (58).

Engler — (51).

Ennis — (48).

Fabre — (25).

Farlow — (42); — (58); — (55).

Faull *3430* (58).

Faxon, E. & C. E. *10, 4, 3, 1, 2, 6, 8* (42); — (48); — (55); *7, 5* (58).

Fernald *220, 218, 219, 105, 1215, y, g, 2819, x, 1214, 2824, 186* (42); *186, y* (55); — (58).

Fernald & Collins *311, 320, 316,154, 318* (42); *155, 319, 317* (54); — (58).

Fernald & Linder *19630, 19631* (55).

Fernald & Long *12340, 12339, 12342, 23113, 12341, 12338, 12343* (42); *19620, 23109, 15949* (55).

Fernald, Long & Linder *19625* (54); *19627* (55).

Fernald, Long & Norton *12337* (42).

Fernald & Smiley *11496* (42).

Fernald & Weatherby *15950* (55).

Fernald & Wiegand *2405, 4411, 4406, 2402, 2401, 4401, 2400, 4410, 4405, 2401, 4407, 4403, 2403* (42); *4409* (54); *2404, 4402* (55).

Fernow *2640* (43).

Fiori & Beguinot *1606* (7).

Fitch — (58).

Flett *1929x* (42); *1930* (42a); *949* (50); *2034* (53).

Fl. Reg. Alg. *16* (10).

Forbes — (42).

Foucault — (11).

Frag. Fl. Alg. Exsic. *499* (15).

Franberg — (51).

Franzoni — (40).

Frost *6* (48); *18* (58).

Fuller — (42); — (58).

Furbish — (42).

Fyson — (5).

Galen — (58).

Gandoger — (10); — (15); — (25); — (62).

Garber — , *2312, 32* (31); — (42).

Gattinger *3812*, — (39).

Gautier — (6).

Gay — (40); — (51); *361* (62); — (11).

Gilbert — (42).

Gillman — (42).

Gorman *715* (42).

Grand Marais — (25); — (62).

Graves *142* (42); *145* (42a); *144* (48a); *139, 140* (55).

Graves & Bissell — (48).

Graves & Linder *19621* (55).

Gray — (29).

Greenman *3861* (38); *2314* (42); *424* (55).

Grout — (42).

Grout & Eggleston — (55).

Gundersen — (42).

Guthnik (?) — (25).

Hall —, *693* (26); —, *859* (38); — (58).

Hamilton *81051* (42); *81051* (55).

Hanbury *1656* (25).

Harper *1010, 1429* (31); *843, 951, 1046* (31a); — (42); *38, 310* (58); *2142, 1112* (58a).

Hartz — (42).

Harvey *2* (42); — , *1, 2, 1411* (54); *4* (54a); *3* (55).

Hector — (18).

Heldreich *899* (4).

Heller, A. A. & E. Gertrude *3482* (34).

Henderson *2894, 2978* (34); *2979, 4786* (52).

Henry *9082* (42).

Hepp *599* (51).

Herb. Ball — (25).

Herb. Copineau — (6).

Herb. Engelmann — (6).

Herb. Fac. Scient. Monsp. — (6).

Herb. Font. norm. *99, 99bis* (15).

Herb. des Flores Europeenes *25* (10).

Herb. Grand Marais — (62).

Herb. Martindale (Cheeseman Coll?) — (18).

Herb. Motelay — (38).

Herb. Mus. bot. Berol. — (40).

Herb. Per Larson — (51).

Herb. Thurber — (48).

Herb. Wight Cryp. *4* (5).

Heribaud — (40); — (51).

Hieronymus *774* (32); — (51).

Hinsdale & Eggleston — (42).

Hitchcock *1068* (39).

Hoffman — (42).

Holt — (42).

Hopkins — (42).
Hornung — (51).
Howe — (34).
Howe & Blasdale — (34).
Howe & Lang *763, 1424* (54); *954* (42).
Howell — , *1521, 698* (34); — , *613, 1526* (26); — (35).
Howell & Howell *303* (26); — (34).
Huet de Pavillon — (15).
Hunt — (58).
Hy — (12); — (41); — (51).
Hylten-Cavallius —, *1771* (51).
Jacquel — (51).
James — (42); — (48).
Jenks — (58).
Jenks & Swan — (48).
Jenman — (35).
Jennings *6582* (42).
Jesup — (42); — (48).
Johnson — (27).
Jones — (34); — (35).
Joor — (38).
Junger — (40).
Kashyap — (5).
Kay — (62).
Kellogg — (35).
Kirk —, *239, 136* (17); — (18).
Klebsman — (51).
Klinsmann — (51).
Knight *14* (54).
Knipe — (58).
Knowlton — (55).
Kralik *187* (25).
Kupffer *14912* (40).
Lagrave — (51).
Le Grand — (12).
Leggett — (58).
Lehman — (63).
Leiberg *1149, 1656, 1663* (34); *39, 2939* (35); *71, 2971* (42).
Lemmon — (35a); — (35).
Le Roy — (40); — (51).
Lesquereux — (42).
LeTourneux — (15); — (15a); — (15b).
Lloyd *198* (25).
Long *12311, 12338* (42).
Lovery — (54).
Lunt — (42); — (58).
Lutzow — (51).
Lyon *874, 875, 876* (42); — (54).
Mabille — (25).
Mackenzie — (38); *1025* (42); *1059* (58).
MacMillan, Lyon & Brand *177, 71, 70, 146, 198, 171, 170* (42).
Macoun *14219a, 14219c, 86378, 533* (26); — , *14212* (35); *14220, 14226, 14224, 14222, 24940,* —, *86379, 14217, 14218, 14215, 14216, 532* (42); *14227* (42a); —(48); *14213, 76921, 84084* (48a); *81092, 14223, 81091* (55).
Magnus — (51).
Malinverni — (7).
Mandon — (6).
Mann — (42); — (58).
Marrson *14* (51).
Martin — (40); *19* (12).
Martindale — (42).
Maxon *432, 3886* (47).
McAllister — (30).
McDaniels *5446* (58).
McMinn — (58).
McMurphy — (34).
Mearns *2807* (35).
Meisner — (51).
Merrill —, *10, 1408* (42).
Milde — (51).
Miller *1, 2* (42).
Milligan — (38).
Morong —, *353* (42); — (48; — (55); — (58).
Motelay — (6); — (10); *1903* (11); — (12); — (25); — (41); — (15a); — (25a).
Mougeot — (51).
Mougeot & Nestler *111* (51).
Mouillefarines — (25).
Mueller — (19).
Munz *479* (58).
Nelson *1531, 3939, 4059* (34); *3737* (26).
Neyraut — (6); — (25a); — (62); — (11).
Nichols *877* (54).
Nolte *1601* (51).
Nuttall — (26); — (48).
Orcutt — , *1242* (27).
Osborn — (20).
Overacker — (58).
Paine — (42).
Palmer *2355* (26); — (47); — (48); *21555, 20848* (39).
Parish *1440* (34).
Parker — (42); — (48).
Parlin *1753* (42).
Parlin & Fernald *922* (42).
Parry — , *307* (35).
Pease *2249, 13790, 2775, 2670* (42); *2640* (55).
Peck — (26).
Perkins — (42).
Perrin — (51).
Pfeiffer *21* (38).
Piper *4209* (34); *2131, 1117* (42); *2125* (50); — , *2317, 1102* (53).

Piper & Hungate — (53).
Piper & Smith *651* (53).
Pl. Seculae *242* (15).
Poring — (51).
Porter *1953* (42); — (58).
Poyser — (48).
Praeger — (54).
Pringle — (35); *1447, 1713, 8796, 3459, 13261, 6660* (37); — (42); — (42a); *3333* (49); — (52); — (34); — (54a).
Rabenhorst *105* (15).
Rand — (42); — , *2, 3* (54); — (55).
Rand & Redfield *3121* (55).
Rand & Robinson *927* (42).
Rau — (48).
Redfield *2530* (42); *2726* (54).
Reess — (40); — (51).
Reinhardt — (16).
Reinke — (51).
Reinsch — (51).
Retter — (51).
Reveliere — (15); — (25).
Reverchon *1177, 795, 3551, 3549,* — (38); — (62); — (25); — (15).
Rich — (42); — (58).
Robbins — (42); — , *7, 8, 9, 11, 14* (48); *10* (48a); — (54); *13* (58).
Robinson *335* (42).
Robinson & Schrenk *239* (55).
Rodway — (19).
Rolland *6284, 65* (42); *6230* (48a).
Rose & Painter *8168, 8216* (58).
Rosendahl *2050* (42a).
Ross — , *800* (62).
Royle — (5).
Rugel —, (31).
Russell — (42).
Ruth & Ruth — (42); — (58).
Rydberg & Bessey *3520* (35).
St. John *90061, 90059, 90060, 90058, 1370, 1371, 630* (42).
Sanford *38* (42).
Sargent *27* (42).
Schildknecht & Thiry — (40).
Schlickum — (40).
Schmoll — (35).
Schonland — (61).
Schrenk — (42).
Schultz *778* (11); *395, 395b* (12); *781* (25).
Schweinfurth — (3).
Schweinitz — (54).
Sennen — (6).
Seymour *1017* (55); — (58).
Shockley — (52).
Shull *66, 67, 296, 305, 200, 201, 252* (47).
Shuttleworth — (62).
Smiley *492, 747* (26).
Smith — (42); — (48); — (53); — (58).
Soc. Bot. Edin. *183* (51).
Soc. Cenom. Exsicc. *482* (6).
Solms & Reess — (40).
Spruce — (21).
Stahl — (40).
Steele — (47).
Stone — (55).
Study — (40); — (51).
Sturtevant — (55).
Suksdorf *2369, 833, 2370, 950, 2368, 1235, 2372, 2613, 2479, 2616, 2618, 642, 2617* (34); *917, 2373, 2364, 2614, 2615, 4443* (26); — , *2375* (35); *2210* (42); *2371, 2365, 2366, 2367* (34a).
Swan — (48).
Tatnall — (58).
Thaxter — (55).
Thiry — (40).
Thomas — (58).
Thompson — (26); — (27); — (34).
Thompson & Thompson — (34); — (27).
Thurber — (58).
Thurow *15* (38).
Tidestrom — (47).
Trelease — (35); *1262, 1261, 1263* (59).
Tuckerman — (55).
Tuerckheim *3531* (36).
Tweedy — , *362, 417* (35); *416* (52).
Umbach — (34).
Underwood — (29); — (42); — (42a); — (54); — (58).
Underwood & Cook — (42a).
Vaccari *503* (25).
Vahl — (42).
Van den Born — (40).
Varnberg — (51).
Vasey — (38).
Vasey & Coville — (47).
Victorin — , *61, 694* (42).
Violleau *427* (12).
von Schrenk $\frac{250}{07}$ (58).
Vroom — (42).
Walker-Arnott — (51).
Wanderley — (6).
Ward — (58).
Ware *724* (42).
Warion *189* (15); — , *187* (25); *188* (10).
Watanabe — (60).
Waters — (42).
Watson *1371* (42).
Webster — (53).
Weddell *16* (10).

Wetherby — (58a).
Wheeler *1227* (42).
Wicketson — (51).
Wiegand *2402* (42).
Williams *1*, — (42); — (58).
Winslow — (42); — (54).
Wolf — (38).
Wright *3912* (8).
Zantziger — (48).
Zeller — (50).
Zickendrath — (40); — (51).

Index to Species

New species, varieties, and combinations are printed in **bold face** type; synonyms and page numbers having reference to plates, in *italics;* and previously published names, in ordinary type.

	Page
Calamaria	104
adspersa	115
aequinoctialis	107
alpina	122
amazonica	125
azorica	207
Bolanderi	143
Boryana	116
Butleri	152
coromandelina	109
cubana	114
Drummondii	125
dubia	118
Duriaei	209
echinospora	154
elatior	127
flaccida	136
Gardneriana	126
Gunnii	124
Hystrix	128
humilior	134
japonica	208
Kirkii	123
lacustris	186
Lechleri	138
longissima	119
Malinverniana	113
melanopoda	149
melanospora	134
Muelleri	127
nigritiana	114
Nuttallii	130
olympica	118
Perralderiana	121
pygmaea	146
riparia	181
saccharata	179
Savatieri	177
Schweinfurthii	107
setacea	110
tegulensis	121
tenuissima	117
tripus	177
triquetra	138
Tuckermani	195
Welwitschii	106

	Page
Cephaloceratodon	104
gymnocarpum	129
hystrix	128
Isoetella	104
Duriaei	209
Isoetes	103
adspersa	115, *220*
aequinoctialis	107
alata	137
alpina	122, *222*
amazonica	125
ambigua	157
Andina	138
azorica	207, *232*
Bolanderi	143, *228*
Bolanderi var. *Parryi*	143
Bolanderi var. pygmaea	146
Bolanderi var. *Sonnei*	143
Boryana	116, *220*
brachyglossa	109
Braunii	156, *230*
Braunii forma **robusta**	173
Braunii var. **maritima**	174
Brochoni	156, *230*
Butleri	152, *228*
Butleri var. *immaculata*	152
californica	143
canadensis	184
canadensis var. *Robbinsii*	184
capsularis	109
Chaboissaei	119
Chapmani	136
coromandelina	109, *218*
cubana	113, *220*
decipiens	119
Delalandei	128
Dodgei	184
Dodgei var. *Robbinsii*	184
Drummondii	125, *224*
dubia	118
Duriaei	209, *232*
Eatoni	177, *230*
echinospora	154, *230*
echinospora var. asiatica	156
echinospora var. *Boottii*	156
echinospora var. *Braunii*	156

	Page
echinospora var. *Braunii* forma *Boottii*	157
echinospora var. *Braunii* forma *robusta*	173
echinospora Brittoni	157
echinospora var. *Flettii*	186
echinospora var. *maritima*	174
echinospora var. *muricata*	157
echinospora var. *robusta*	173
echinospora var. *truncata*	175
edulis	208
elatior	126
Engelmanni	201, *232*
Engelmanni var. caroliniana	207, *232*
Engelmanni var. *fontana*	201
Engelmanni var. *gracilis*	201
Engelmanni var. *valida*	201
flaccida	136, *226*
flaccida var. **alata**	137, *226*
flaccida var. *Chapmani*	136
flaccida var. *rigida*	136
Flettii	186, *230*
foveolata	200, *232*
Gardneriana	126
Gravesii	173
Gunnii	124, *224*
Harveyi	192
Heldreichii	109
heterospora	192
hieroglyphica	194
histrix	128, *224*
histrix forma *desquamata*	129
histrix forma subinermis	129
histrix var. *scutellata*	129
Hookeri	134
Howellii	139, *228*
Howellii var. **minima**	142
humilior	134
japonica	208
Karstenii	138
Kirkii	123, *222*
lacustris	186, *230*
lacustris	124, 192
lacustris var. *paupercula*	189
Lechleri	138
leiospora	186
ligustica	209
lineolata	115
lithophila	135, *226*
longissima	120
Macounii	174
macrospora	192, *232*
macrospora var. *heterospora*	192
macrospora forma **hieroglyphica**	194, *232*
Malinverniana	113, *218*
maritima	174
Martii	200
melanopoda	149, *228*
melanopoda var. *californica*	139
melanopoda var. *pallida*	149
melanospora	134, *226*
mexicana	147, *228*
minima	142
Montezumae	147
Muelleri	127
muricata	157
natalensis	210
neoguineensis	211
nigritiana	114
nuda	139
Nuttallii	130, *224*
Nuttallii var. *Orcuttii*	132
occidentalis	189, *230*
occidentalis var. *Piperi*	190
olympica	118
opaca	130
Orcuttii	132, *224*
ovata	108, *218*
paupercula	190
Perralderiana	121
phaeospora	176
Piperi	190
Pringlei	185, *230*
pygmaea	146
riparia	181, *230*
riparia var. canadensis	184, *230*
saccharata	179, *230*
saccharata var. *Palmeri*	179
saccharata var. *reticulata*	179
Savatieri	177
Schweinfurthii	107, *218*
setacea	110, *218*
setacea var. *Delilei*	119
setacea var. *Perreymondii*	115
socia	138
Stuartii	134
Suksdorfii	130
tasmanica	127
tegulensis	121, *222*
tenuissima	117, *220*
tenuissima	127
Tiguliana	121
tridentata	209
tripus	176
triquetra	138
truncata	175, *230*
Tuckermani	195, *234*
Tuckermani var. *borealis*	195
Tuckermani var. *Harveyi*	192
Tuckermani var. *heterospora*	192
Tuerckheimii	147, *228*
Underwoodi	139
valida	177, 201
valida var. *Gravesii*	173
velata	119, *222*
valata forma **longissima**	120
velata var. *longissima*	120
velata var. **Perralderiana**	121, *222*
Viollaei	117
Welwitschii	106
Wormaldii	208
Marsilea	104
Subularia	104

Explanation of Plate

In this and the following plates, which are reproductions of photographs, the magnification is approximately 21 diameters in all cases of megaspores.

PLATE 12

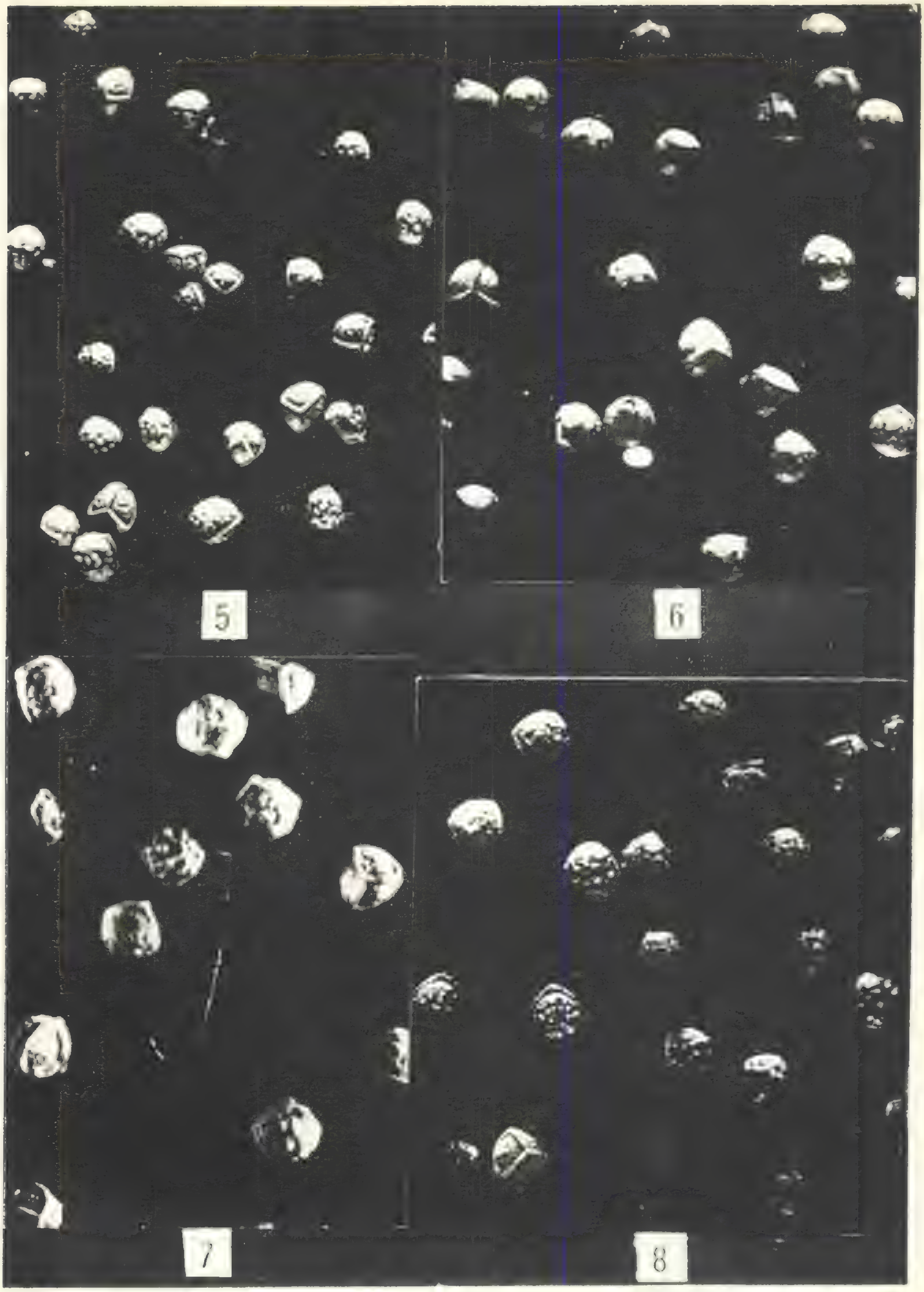
Fig. 1. *Isoetes Schweinfurthii* A. Br. Megaspores.
Fig. 1a. *I. ovata* Pfeiffer. Megaspores.
Fig. 2. *I. coromandelina* L. fil. Megaspores.
Fig. 3. *I. setacea* Bosc. Megaspores.
Fig. 4. *I. Malinverniana* Cesat. & De Not. Megaspores.

PFEIFFER—MONOGRAPH OF ISOETACEAE

Explanation of Plate

PLATE 13

Fig. 5. *Isoetes cubana* Engelm. Megaspores.
Fig. 6. *I. adspersa* A. Br. Megaspores.
Fig. 7. *I. Boryana* Dur. Megaspores.
Fig. 8. *I. tenuissima* Boreau. Megaspores.



PFEIFFER—MONOGRAPH OF ISOETACEAE

Explanation of Plate

PLATE 14

Fig. 9. *Isoetes velata* var. *Perralderiana* Pfeiffer. Megaspores.
Fig. 10. *I. velata* A. Br. Megaspores.
Fig. 11. *I. tegulensis* Genn. Megaspores.
Fig. 12. *I. alpina* Kirk. Megaspores.
Fig. 13. *I. Kirkii* A. Br. Megaspores.

PFEIFFER—MONOGRAPH OF ISOETACEAE

Explanation of Plate

PLATE 15

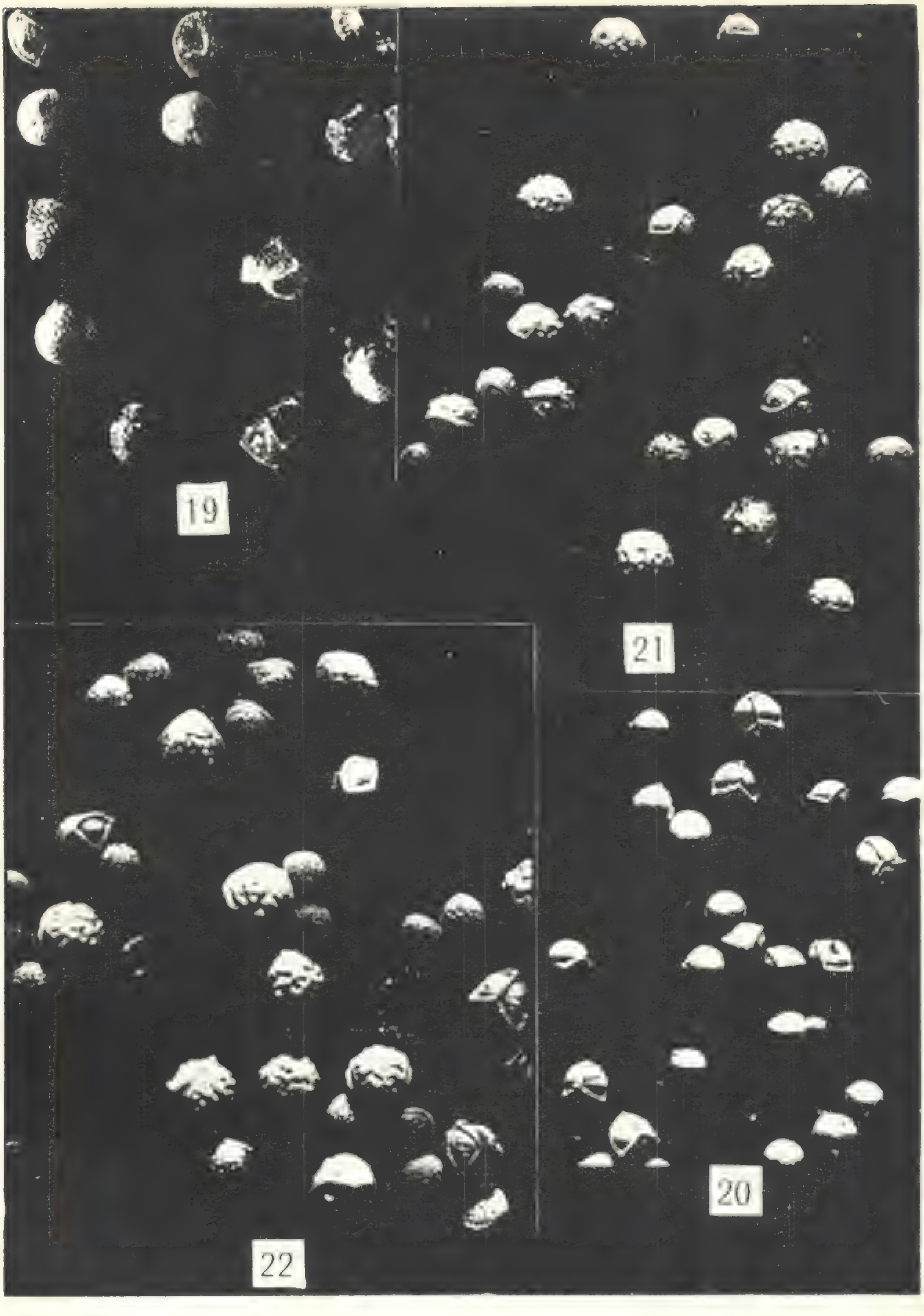
Fig. 14. *Isoetes Gunnii* A. Br. Megaspores.
Fig. 15. *I. Drummondii* A. Br. Megaspores.
Fig. 16. *I. histrix* Bory & Dur. Megaspores.
Fig. 17. *I. Nuttallii* A. Br. Megaspores.
Fig. 18. *I. Orcuttii* Eaton. Megaspores.

14
15
16
17
18

Explanation of Plate

PLATE 16

Fig. 19. *Isoetes melanospora* Engelm. Megaspores.
Fig. 20. *I. lithophila* Pfeiffer. Megaspores.
Fig. 21. *I. flaccida* Shuttlew. Megaspores.
Fig. 22. *I. flaccida* var. *alata* (Small) Pfeiffer. Megaspores.



PFEIFFER—MONOGRAPH OF ISOETACEAE

Explanation of Plate

PLATE 17

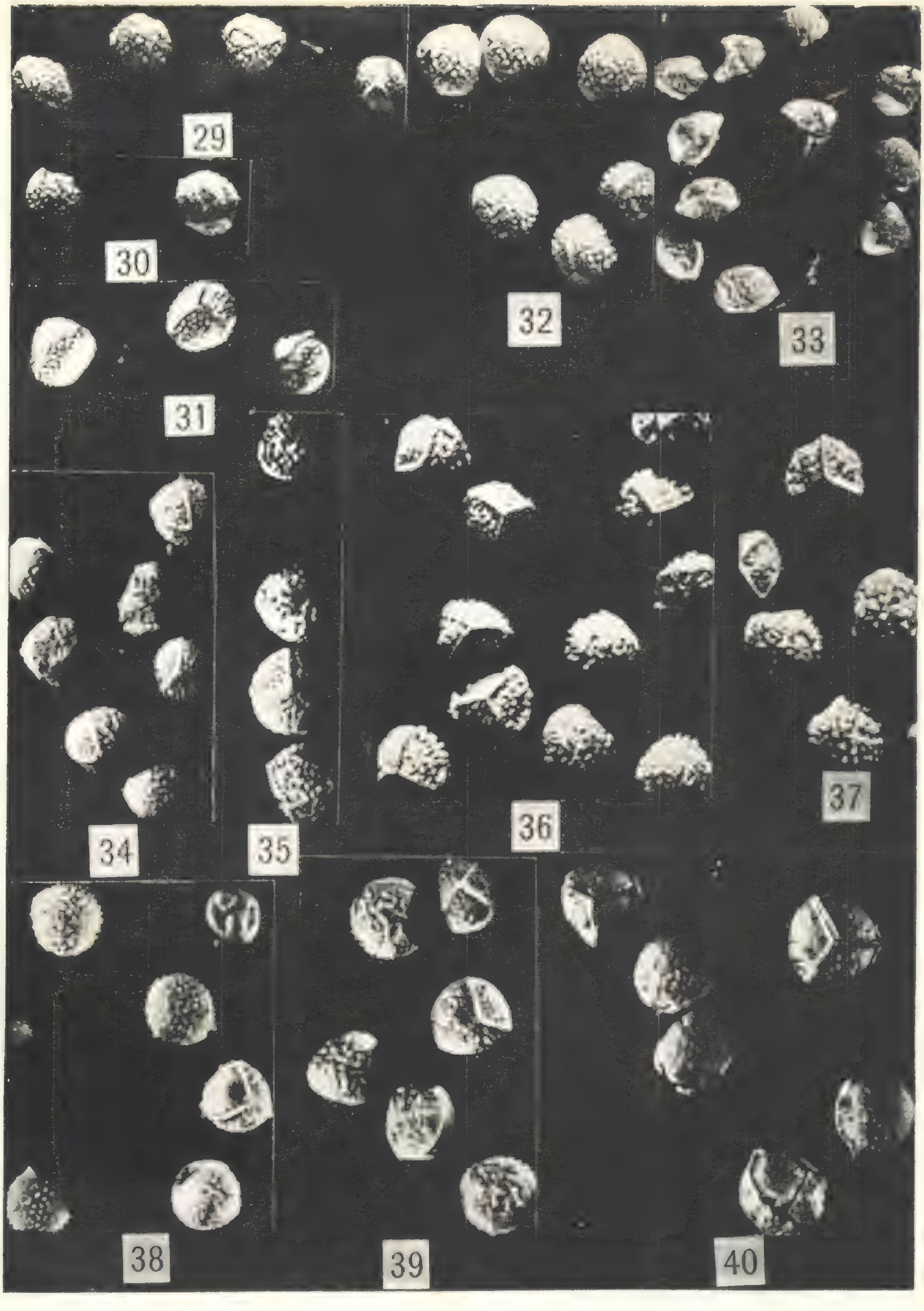
Fig. 23. *Isoetes Howellii* Engelm. Megaspores.
Fig. 24. *I. Bolanderi* Engelm. Megaspores.
Fig. 25. *I. Tuerckheimii* Brause. Megaspores.
Fig. 26. *I. mexicana* Underw. Megaspores.
Fig. 27. *I. melanopoda* Gay & Dur. Megaspores.
Fig. 28. *I Butleri* Engelm. Megaspores.

PFEIFFER—MONOGRAPH OF ISOETACEAE

Explanation of Plate

PLATE 18

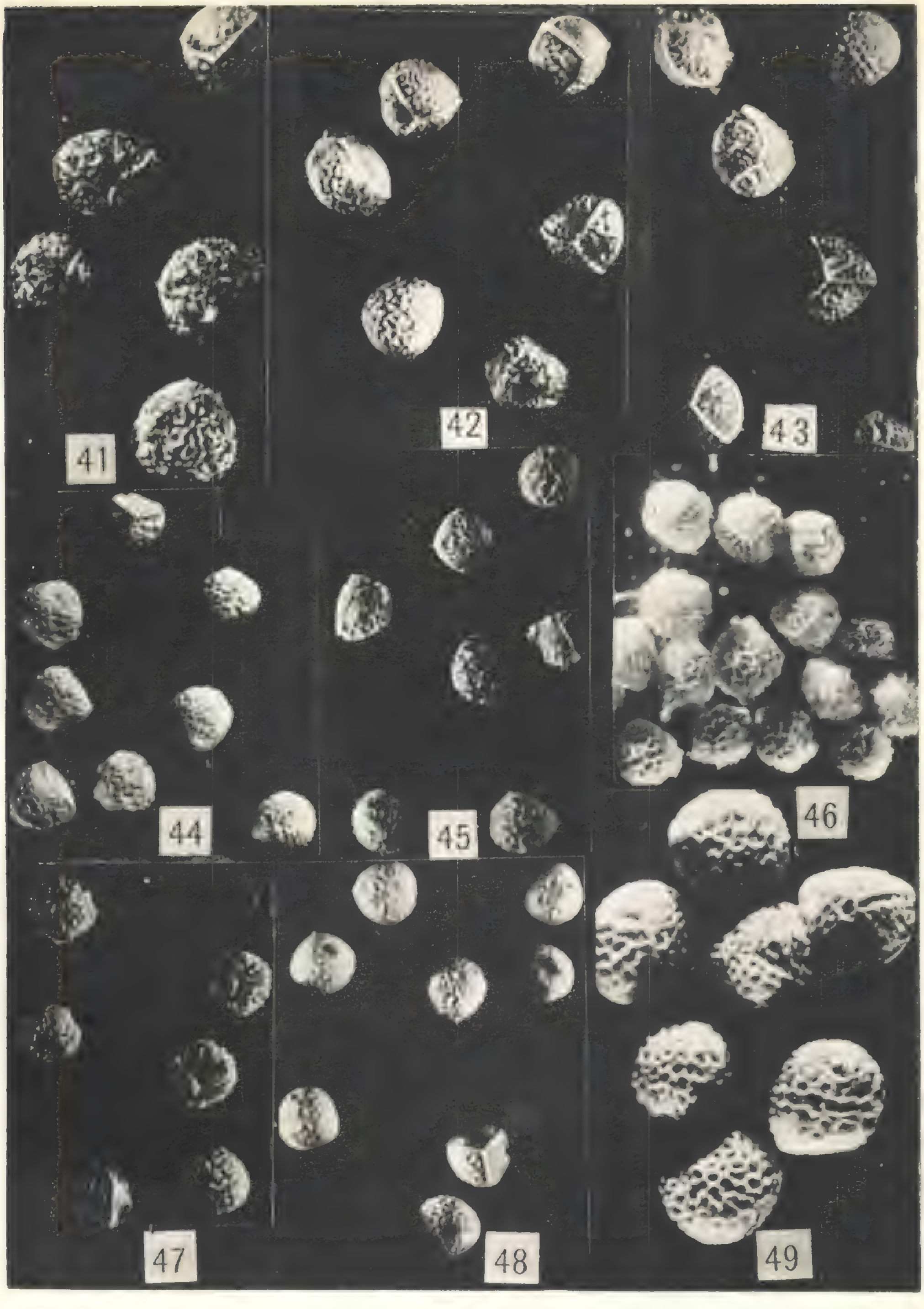
Fig. 29. *Isoetes echinospora* Dur. Megaspores.
Fig. 30. *I. Brochoni* Motel. & Vendr. Megaspores.
Fig. 31. *I. Braunii* Dur. Megaspores.
Fig. 32. *I. truncata* Clute. Megaspores.
Fig. 33. *I. Eatoni* Dodge. Megaspores.
Fig. 34. *I. saccharata* Engelm. Megaspores.
Fig. 35. *I. riparia* Engelm. Megaspores.
Fig. 36. *I. riparia* var. *canadensis* Engelm. Megaspores.
Fig. 37. *I. Pringlei* Underw. Megaspores.
Fig. 38. *I. Flettii* (Eaton) Pfeiffer. Megaspores.
Fig. 39. *I. lacustris* L. Megaspores.
Fig. 40. *I. occidentalis* Hend. Megaspores.


29
30
31
32
33
34
35
36
37
38
39
40

Explanation of Plate

PLATE 19

Fig. 41. *Isoetes macrospora* Dur. Megaspores.
Fig. 42. *I. macrospora* f. *hieroglyphica* (Eaton) Pfeiffer. Megaspores.
Fig. 43. *I. Tuckermani* A. Br. Megaspores.
Fig. 44. *I. foveolata* Eaton. Megaspores.
Fig. 45. *I. Engelmanni* A. Br. Megaspores.
Fig. 46. *I. Engelmanni* A. Br. Megaspores with dust-like microspores in the background, showing relative size.
Fig. 47. *I. Engelmanni* var. *caroliniana* Eaton. Megaspores.
Fig. 48. *I. azorica* Dur. Megaspores.
Fig. 49. *I. Duriaei* Bory. Megaspores.



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A MONOGRAPHIC STUDY OF THELYPODIUM AND ITS IMMEDIATE ALLIES[1]

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Introduction

The present study was made with at least two objects in view; it was desired to continue investigations on the phylogeny of the *Cruciferae* and at the same time to attack a problem that would yield results of practical taxonomic value. These two objects, although distinct in their purpose, were of course very closely associated throughout the work. The taxonomy is but the expression of the phylogenetic conclusions. Recent studies in this family have emphasized the necessity of detailed examination of the various generic units before any general developmental theory is possible. The present author holds that there is no basis for a study of phylogeny equal to a taxonomic review of the species and genera involved. Details of specific distinction are most important in illustrating the steps in progressive differentiation. The present view held is that phylogenetic theories that do not take into account the apparently trivial details of specific characterizations are not dependable, since they are subject to too many sources of error. In the study of evolution the taxonomist's part is to lay down the broader lines of interspecific and generic change and point the direction of the current of progress. Where he leaves off, the work of the geneti-

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cist begins. The one study is incomplete without the other. With these two objects in mind, that is, phylogeny and taxonomy, no more promising field was seen than the group of genera here presented. Recent students of the *Cruciferae* have almost unanimously considered these genera among the most primitive in the family, and therefore it was thought that here phylogenetic studies would yield the most significant results. It was further realized that in no other group of American *Cruciferae* was the synonymy so involved due to the many interpretations of generic limits and the consequent segregation of genera and multiplication of nomenclatorial combinations. Furthermore, the species themselves are rather polymorphic and seem to lack convenient and easily definable differences. Here was a group that needed revision greatly in order to confirm or reject changes recently proposed. Since to *Thelypodium* were referred the largest number of species in this group it was taken as a reference point, and the related genera were investigated as the work progressed.

The study here reported was carried on at the Missouri Botanical Garden whose splendid library and herbarium were at the author's disposal at all times. For these privileges he is deeply indebted to the Director, Dr. George T. Moore. Assistance, encouragement and helpful criticism were given without stint by Dr. J. M. Greenman. To him especially is the author under great obligations. Herbarium specimens were borrowed from the Rocky Mountain Herbarium at the University of Wyoming, the Herbarium of the University of California, the Gray Herbarium, the United States National Herbarium, and the herbaria of Prof. Ellsworth Bethel and Mr. I. W. Clokey of Denver, Colorado. To these institutions and individuals the author wishes to express his gratitude. Much assistance in many ways was also rendered by the author's wife.

I. Phylogeny and General Morphology

THELYPODIUM

This genus, as limited in the following taxonomic treatment, contains but a small number of the species that have at one time or another been referred to it. The following remarks, of course, concern only the species recognized by the writer as belonging to the genus in this limited sense. *Thelypodium* thus restricted becomes a homogeneous group of limited geographical distribution and is presumably of monophyletic origin. It is the purpose

of these remarks to demonstrate the general characteristics of the common ancestor, the phylogenetic sequence of characters, and to correlate these findings with the geographical distribution of the various units.

The gynophore.—Thelypodium received its name because of a gynophore or stipe that in many species raises the ovary and fruit above the torus. Of the fourteen species in the genus, seven are found to possess a distinct stipe and in the others the ovary is not quite sessile. Five species of the seven show a stipe that at least occasionally reaches a length of two millimeters. It is most highly developed in *T. laciniatum* and *T. eucosum,* being usually more than two millimeters long. What is the significance of this stipe?

Recent students of the *Cruciferae* are nearly unanimous in the belief that this family has been derived from the *Capparidaceae* or from capparidaceous-like ancestors. In this connection it is sufficient to refer to the writings of Hallier,[1] Lotsy,[2] von Hayek,[3] and Engler and Gilg.[4] In the *Capparidaceae* a stipe is almost universally present and is often very long. Granting this relationship between the two families, the presence of a stipe in the *Cruciferae,* in which it is not of common occurrence, must be considered either a primitive character or an atavistic variation. For the sake of argument and as a point of attack the stipe in this group will be assumed to be a primitive characteristic. The question now arises: Are the two species that possess the longest stipe primitive in other respects?

The pods.—In many genera of the *Cruciferae* the capsules or pods are known to display characters of the utmost importance taxonomically. This is not true of *Thelypodium* to such an extreme degree, except as regards the cellular structure of the septum. The capsules are often particularly variable in length. They are usually terete, glabrous, and many times longer than wide. Frequently the valves are somewhat constricted between the seeds and the pod becomes torulose in consequence. In two species, *T. laciniatum* and *T. affine,* the valves are slightly compressed parallel to the septum. It has been found impossible to attach much phylogenetic importance to this character within

[1]Hallier, H. Provisional scheme of the natural (phylogenetic) system of flowering plants. New Phytol. **4**:157. 1905.
[2]Lotsy, J. P. Vorträge über botanische Stammesgeschichte **3**:915–916. 1911.
[3]von Hayek. Entwurf eines Cruciferen-Systems auf phylogenetischer Grundlage. Beih. Bot. Centralbl. **27**[1]: 176–178. 1911.
[4]Engler, A. und Gilg, E. Syllabus der Pflanzenfamilien, 8th ed., 201. 1919.

the genus, and it has evidently appeared separately in the two species mentioned since they are not closely related. In *Caulanthus* it would seem that flattened pods have been derived from terete ones, and there appears to be no reason to imagine a different sequence in *Thelypodium*.

Although the length of the pods is not of great value in specific determination, the average length is of considerable interest. The longest pods are found in *T. laciniatum* and its varieties. These range in length from about three centimeters to at least twelve. Other species with long pods are *T. sagittatum*, *T. eucosum*, *T. stenopetalum*, *T. Howellii*, and *T. vernale*. The identity of the last is in doubt, and since it may not belong in this genus it scarcely deserves mention. Reduction in the number of seeds has been found in another genus of this family (*Lesquerella*) to be correlated with divergence from the ancestral type, and this might be supposed to apply also to *Thelypodium*. Decrease in the length of the pods is a crude measure of reduction in the number of ovules. To consider long pods primitive and short ones derived is at least in keeping with what would be expected from previous studies. It will be remembered that *T. eucosum* and *T. laciniatum* were the two species with the longest stipes—it is significant that in these species long pods occur.

Style and stigma.—In all the species of *Thelypodium* the style is short and the stigma small and scarcely, if at all, lobed. No characters of taxonomic or phylogenetic importance have been observed here.

Septum.—The cellular pattern of the septum in this genus is very characteristic. Extending nearly or quite from end to end of the pod through the middle of the septum there is a broad region composed of cells elongated parallel to the marginal framework. This region covers from about one-fourth to one-half of the surface of the septum and there the cell-walls are more or less closely compacted. In some species this dense band is yellowish and then it becomes conspicuous even under a hand lens. Such a condition is noticed in *T. integrifolium* and its immediate allies, in *T. flexuosum*, and to a lesser degree in *T. crispum*. The two marginal bands that occur on either side of the dense middle region often differ in different species. The cells in this area are always short and may be more or less rectangular with somewhat tortuous walls or may be irregular and elongated at right angles to the margin. But little use has been

made of differences in the septum to distinguish the species, but as a generic character the pattern is of great importance. No species are now admitted to *Thelypodium* that do not exhibit this type of septum. There are, however, species outside the genus that have apparently developed a similar type independently.

It would be difficult to trace any developmental series in the character of the septum, but it is of some interest to notice that in *T. laciniatum,* which has been found primitive in at least two respects, the cell-walls in the middle region are not so closely compacted as in certain other species. The septum of *T. eucosum* is not known.

Seeds.—As far as present studies show, the seeds in this genus are very uniform and furnish no characters of taxonomic or phylogenetic importance. In common with related genera the position of the radicle in the species of *Thelypodium* is almost invariably oblique with reference to the cotyledons. Occasionally the seeds are slightly pointed or apiculate but are never winged or conspicuously margined.

The flowers.—In common with most of the members of this family the flowers of *Thelypodium* do not exhibit much variation. Only two points need be considered here, the shape of the petals and their color. In shape they vary from narrowly linear, as in *T. stenopetalum,* to broadly oblanceolate, as in *T. flexuosum.* Since neither of these species is primitive as to length of stipe or pod it seems probable that neither of these two extremes represents the ancestral type for the genus. Rather we would be inclined to suppose a broadly linear or long-spatulate form more nearly like the original, since it occurs in *T. laciniatum, T. eucosum,* and certain other species that seem primitive in other respects. Within the genus the petals are never conspicuously crisped or channeled as in *Caulanthus;* they are always entire and there is rarely any differentiation between blade and claw.

In color the petals of the various species range from red-purple to blue and white. No species with yellow petals is known. *T. laciniatum* has white petals, and *T. eucosum* has red-purple ones. Within specific limits the range in color is often extreme, as in *T. lilacinum* in which the petals vary from deep purple to white. There is indication, however, that the color forms are more or less isolated geographically and therefore the variation may have its phylogenetic significance. The form of that species that occurs in the eastern part of its range seems to be almost entirely white.

There are some reasons for suspecting that the original color of the flowers of this genus were purple and that this color gave rise to white. The best evidence to be obtained on this question, however, comes from an examination of related genera and will be considered in another paragraph. This much may be said from a study of *Thelypodium* alone: there is no reason to doubt such an hypothesis even though there is little to confirm it.

Inflorescence.—The characters of the inflorescence have been utilized to considerable extent in specific delimitation. As in most *Cruciferae* the flowers in this genus are borne in a raceme and are not subtended by bracts or leaves. Two different types are recognized in *Thelypodium.* The first is characterized in the key and descriptions as "racemose." By this is understood that type exhibited by *T. brachycarpum* or *T. Howellii* for example. In these species and some others the flowers when they open are some distance below the apex of the cluster. In *T. brachycarpum* the raceme is dense and in *T. Howellii* lax. This distinction obtains between other species. The second condition is described as "corymbose." It is illustrated by *T. sagittatum* and *T. flexuosum.* In those species the flowers when they open are near the apex of the inflorescence and form a somewhat flat-topped cluster. In both the racemose and corymbose types the inflorescence when mature is elongated and truly racemose. In the key and descriptions "inflorescence" means the flower cluster—by "mature inflorescence" is meant the arrangement of the pods upon the axis.

There are also several good taxonomic characters to be obtained from a study of the pedicels. The position is either horizontal or ascending, and there is little variation between individuals of a given category in this respect. Some species are well characterized by very short pedicels, others have slender ones which may or may not be slightly flattened at the base.

For several reasons it has been thought that the primitive inflorescence was elongated even before anthesis, that it was probably rather dense, and that the pedicels were short and stout, perhaps angled and probably horizontal. Such a condition may be observed in *T. eucosum, T. laciniatum* and its variety *streptanthoides, T. brachycarpum,* and others. This type seems to predominate in those species that may be considered primitive in other respects. It is also significant that in *Stanleya,* a closely related genus and one that is more primitive than *Thelypodium* in many respects, the inflorescence is universally dense and the pedicels are horizontal.

Leaves.—The species of *Thelypodium* may be grouped in three divisions according to the shape of the stem-leaves. In nine species they are entire and amplexicaul at the base. In *T. laciniatum* and its varieties they are irregularly toothed or lobed and more or less petioled. In the remaining four species the leaves are entire but not auriculate at the base. Within the genus there is in all the known species a differentiation between cauline and radical leaves. The radical leaves are generally oblanceolate in outline and entire or subentire. In only four species are they conspicuously toothed, namely, *T. brachycarpum, T. crispum, T. Howellii,* and *T. laciniatum.* In many species a definite petiole is present.

Among those species having entire amplexicaul stem-leaves the most primitive in respect to the length of the stipe, the type of inflorescence, and the form and color of the petals is undoubtedly *T. eucosum;* the most specialized in these and other characters is *T. flexuosum.* In the former the basal lobes are well developed, in the latter they are more reduced than in any other species of this group. From *T. eucosum* the other species with amplexicaul stem-leaves may be derived without difficulty. Among the species having entire but not amplexicaul stem-leaves it would be hard to say which is the most primitive. That there is no great gap between this group and the first is shown by the fact that in *T. lilacinum* (and probably in others) small auricles are sometimes present at the base of the leaves. It seems more probable that this type of leaf was derived by the reduction of the basal lobes than that the change was in the other direction. It remains now to consider the third type of leaf—the lobed and petioled stem-leaves of *T. laciniatum.* Unlike *T. eucosum, T. laciniatum* has no near relatives. It seems to represent an ancient offshoot from primitive stock rather than to be the ancestor of species now extant. It may have been derived from a species with amplexicaul leaves but there is no reason to suppose that it has given rise to species with that type of leaf, since they can be traced to a different ancestry. The entire amplexicaul stem-leaf is considered the earlier type and from it the others are believed to have been derived. In *Lesquerella* it was shown that those species having this type of stem-leaf were primitive; it is not surprising to find the same order of development obtaining in another genus of the same family.

Because of comparative uniformity in the differentiated radical leaves in this genus there is little evidence relating to the steps

in this differentiation between radical and cauline leaves. Have these basal leaves been developed from amplexicaul stem-leaves or has the change been in the other direction? Judging by analogy with *Caulanthus*, in which genus the problem does not seem particularly difficult, it is supposed that the original radical leaf was entire and amplexicaul and that it has given rise to the petioled, lobed leaf independently from time to time. There seems to be a constant tendency for entire leaves to become lyrate-lobed or pinnatifid within the *Cruciferae* in general, although an advance into xerophytic conditions seems frequently to be accompanied by the reverse order.

Trichomes.—Nine species of *Thelypodium* are entirely glabrous and the other five vary from glabrous or nearly glabrous to quite densely pilose near the base. The trichomes are usually long and always unicellular and unbranched. No specific specialization of trichome structure has been noticed in this genus. The plants are ordinarily more or less glaucous as well as glabrous.

Those two species, *T. eucosum* and *T. laciniatum,* which have been considered primitive are glabrous, and because of lack of evidence to the contrary it is assumed that the glabrous condition gave rise to the pubescent one. The change is apparently not a difficult one since in the same species glabrous and pubescent individuals occur. It is of interest to note that the trichomes when they are present, appear only near the base of the plant. This correlates in a significant way with the theory of the origin of radical from stem-leaves as will be discussed under *Caulanthus.*

Duration.—All but three species of this genus are evidently biennial, and of these three two are usually biennial but may persist for several years, as *T. sagittatum* and *T. ovalifolium.* One only is definitely perennial as may be seen from the numerous remains of former leaf-bases that clothe the caudex in *T. flexuosum.* A definite assumption of the perennial habit doubtless represents a specialized condition. With this perennial habit is closely correlated the differentiation between stem and radical leaves in which the latter form a definite rosette. The otherwise more primitive species of the genus are biennial, and the perennial or partially perennial species are the more specialized ones. It is therefore assumed that the biennial preceded the perennial habit in *Thelypodium.*

The generic limits of Thelypodium.—As stated elsewhere, many species have been referred to this genus that are not now

included in it. No attempt will be made in the present paper to place all these species generically. All that now may be said as to many of them is that they may not be included in *Thelypodium*. This does not mean that the various segregate genera recently proposed by Dr. P. A. Rydberg will necessarily be maintained by the present author—it does mean that their affinities are not with this genus.

Pleurophragma.—This group was proposed as a genus by Dr. Rydberg to include *Thelypodium integrifolium* and its immediate allies and was based primarily on the presence of a "strong and broad midrib of the septum of the pod." It was also stated that "there is no distinct midvein in any of the typical *Thelypodia*." Another character that might be used to support *Pleurophragma* is found in the leaves. They are here sessile, entire, and not amplexicaul—a combination that obtains in no species of *Thelypodium* except in this group. That this character, while useful in a key, is of no very great phylogenetic significance, is shown by the occasional appearance of auriculate lobes at the base of the leaves in individuals of *T. lilacinum*. In these exceptional cases the leaves are not unlike those of the amplexicaul group. The value of the "strong and broad midrib of the septum" is scarcely of more importance. The cellular pattern of the septum has already been discussed, and it has been shown that in all the species of *Thelypodium* there is a differentiated middle region where the cells are elongated parallel to the replum and the cell-walls more or less closely compacted. No other "pattern" occurs in the species transferred to *Pleurophragma* although here the extreme in differentiation is probably reached. The "strong and broad midrib" results from the fact that in these species the dense middle zone is colored yellow and so stands out in contrast to the marginal cells. Furthermore, this differential coloring of the middle region is not peculiar to *T. integrifolium* and its allies. It is also seen in *T. flexuosum* and in individuals at least of *T. crispum*. From a morphological viewpoint it would seem impossible to retain *Pleurophragma* as distinct from *Thelypodium*.

The phylogenetic relationships of the species of "*Pleurophragma*" among themselves are not clear. This is due in part to the slight differentiation between the species and in part to the evidence offered by *T. rhomboideum* var. *gracilipes*. Two hypotheses seem possible: first, it might be supposed that the group originated in western Colorado or Utah and that *T. rhomboideum*

var. *gracilipes* is the most primitive form since it possesses the longest stipe. On this theory *T. rhomboideum* would be derived from it and have given rise to *T. lilacinum*, *T. integrifolium*, and *T. affine*. From what is known of the frequently limited distribution of primitive species in other genera, the restricted range of the variety *gracilipes* would seem to argue that it is a primitive form. If this theory is accepted it is necessary to suppose that the group in question was derived from some wide-ranging primitive species of *Thelypodium* that is now extinct.

The second hypothesis as to the origin of "*Pleurophragma*" is that the species developed from the same plexus as did *Thelypodium* proper. *Thelypodium rhomboideum* may be thought of as the most primitive form. It gave rise to *T. integrifolium* on the north and to *T. affine* on the south. One specimen has been seen from western Colorado (*Goodding 1789*) that seems intermediate between *T. rhomboideum* and *T. lilacinum*. In this region, probably, *T. lilacinum* was developed from the other species. The variety *gracilipes* with its long stipe would, according to the second hypothesis, be considered an atavistic variation of *T. rhomboideum*. It is then not necessary to imagine an extinct, wide-ranging species of *Thelypodium* to account for the long distance of the variety *gracilipes* from the plexus of *Thelypodium* proper. Except for the stipe the variety *gracilipes* is not more primitive than *T. rhomboideum*. The present author favors the second theory as being the more probable. In either case "*Pleurophragma*" could scarcely be considered worthy of generic rank, but under the first hypothesis it has somewhat greater phylogenetic justification.

Thelypodiopsis.—Perhaps the most perplexing of the segregate genera is "*Thelypodiopsis*." The species transferred here are very similar in appearance to *Thelypodium sagittatum* and at a casual glance some are likely to be confused with it. There are, however, certain technical differences that should not be overlooked. Most important of all is the septum. It is here a uniform membrane quite different from that of *Thelypodium* with its differentiated middle band. The stigma in "*Thelypodiopsis*" is usually distinctly lobed with the lobes extended over the placentae; in *Thelypodium* it is ordinarily quite entire or rarely may show a tendency for the lobes to be extended over the valves. From a phylogenetic viewpoint the two groups are well differentiated. "*Thelypodiopsis*" seems to have had its origin in northern Arizona and the species have spread both north and

south from there. The plant that is supposed to represent the most ancient type of "*Thelypodiopsis*" is *Thelypodium ambiguum* Wats. It is not here transferred to the segregate genus because the author does not yet wish to recognize "*Thelypodiopsis*" as worthy of generic rank. *Thelypodium ambiguum* must be associated with "*Thelypodiopsis*" *elegans* (Jones) Rydb. and

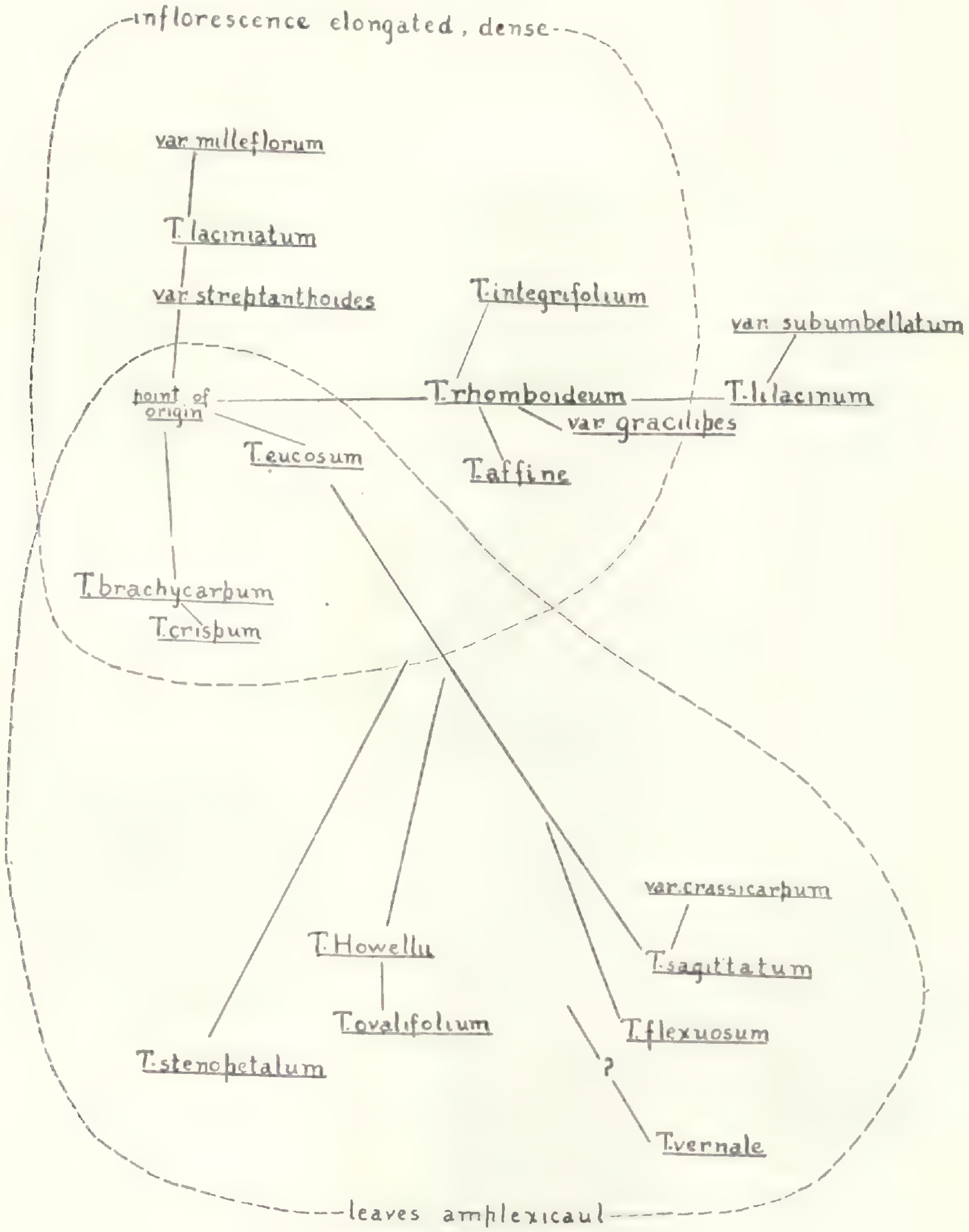

Fig. 1. Phylogenetic chart of the species of Thelypodium.

"*T.*" *aureum* (Eastwood) Rydb. wherever they may be placed eventually. The limits of "*Thelypodiopsis*" are not yet determined.[1]

GEOGRAPHICAL DISTRIBUTION

The genus *Thelypodium* as limited in the present paper has a comparatively restricted distribution. The species are mostly confined to the region between the Cascade or Sierra Nevada Mountains of extreme western North America and the Rocky Mountains of Montana, Wyoming, and Colorado. No species are known from Canada or from Mexico. One doubtful plant, *T. vernale,* occurs in New Mexico. *Thelypodium stenopetalum* is found in the San Bernardino Mountains of southern California: the most southern point known for the genus. Two species with their varieties are found in the Rocky Mountains and have crossed the Continental Divide in several places. *Thelypodium lilacinum* reaches western Nebraska and this marks the easternmost known extension of *Thelypodium*. The genus is richest in species in eastern Oregon.

Thelypodium may be supposed to have originated in or not far from the eastern Oregon region. Several reasons may be advanced to support this conclusion: (1) The greatest specific concentration occurs in this region. (2) Those species held previously to be the most primitive occur here. (3) Conversely, those species farthest from this region show in general those characters considered to be of most recent development. (4) In this region also occurs a genus with more primitive characters than *Thelypodium* from which *Thelypodium* may have arisen. This genus is *Stanleya.* (5) From here is known that species of *Stanleya* which is annual, has amplexicaul stem-leaves, and no differentiated basal rosette—characters common in *Thelypodium* but rare in *Stanleya.* This species is *Stanleya confertiflora* (Robinson) Howell.

In general the members of *Thelypodium* prefer a rather strongly saline soil that at one season of the year at least is wet. Consequently they are usually found on bottom lands rather than on rocky hillsides. No species have become adapted to an alpine habitat.

[1]Species of this group and related forms have been recently treated as species of *Sisymbrium* by the author in Univ. Wyo. Publ. Bot. **1**: 1–27. 1922.

SUMMARY OF CONCLUSIONS ON THELYPODIUM

1. A long stipe or gynophore that raises the ovary or pod above the torus is believed to be a primitive character.

2. Similarly, a long, terete pod is considered more primitive than a short or compressed one.

3. The cellular pattern of the septum is thought to be very important as a generic character but is found to show few specific differences.

4. The ancestral species of this genus are supposed to have had broadly linear or long-spatulate petals that were probably reddish in color.

5. The dense, racemose inflorescence is held to be primitive and from it have probably been derived the lax, racemose, and the corymbose types.

6. The pedicels are thought to have been horizontal in the primitive species. They were also, perhaps, rather stout.

7. The leaves of the ancestral species were probably entire and amplexicaul.

8. Trichomes are not present in the more primitive species of the genus, and their appearance is held to be a sign of specialization.

9. The biennial habit of growth is more primitive than the perennial, but it was probably derived from the annual at no very remote period.

10. This genus is believed to have originated in eastern Oregon or not far from there.

11. *Thelypodium* probably arose from *Stanleya* or some Stanleya-like species.

12. Those species formerly included in *Thelypodium* but recently segregated under the name *Thelypodiopsis* are not referable to *Thelypodium*.

13. The segregate genus *Pleurophragma* is not considered worthy of generic rank and its species are referred to *Thelypodium*.

CHLOROCRAMBE

The genus *Chlorocrambe* is maintained by the present writer chiefly because of the doubtful phylogenetic position that may be assigned to its single species. When first discovered this plant was placed in *Caulanthus* by Dr. Watson without question as to the propriety of such a disposition of it. Dr. Rydberg, when he raised *C. hastata* to generic rank, named three charac-

ters by which this species was different from species of *Caulanthus*. The calyx in *Caulanthus* was described as urn-shaped and more or less closed, while in *Chlorocrambe* it is open; the petals of *Caulanthus* were thought to be of the type seen in *C. crassicaulis*, narrow, channeled, crisped and recurved, while in *Chlorocrambe* they are flat, dentate, and have short claws; the stigma of *Caulanthus* was described as conspicuous and two-cleft, while in *Chlorocrambe* it is entire and small. These characters do serve to distinguish it from such species of *Caulanthus* as *C. crassicaulis*, *C. major*, *C. glaucus*, and *C. pilosus*. These are the species nearest to it geographically. If *Caulanthus* is accepted in the larger sense, however, these characters alone are not sufficient to warrant its generic segregation. In *Caulanthus anceps*, for example, the sepals are spreading and the calyx not at all urn-shaped; in *C. lasiophyllus*, *C. Cooperi*, and *C. anceps* the petals are flat and the proportions of the claw and the blade not essentially different; in *C. amplexicaulis* the stigma is quite entire. There are two characters at least possessed by *C. hastata* that are not admitted to *Caulanthus*—the toothed petals and the definite stipe.

In spite of its several points of agreement with species of *Caulanthus* and its habital resemblance to certain species, the evidence at hand goes to show that this plant has more probably been derived from *Thelypodium* or some immediate ancestor of that group than from *Caulanthus*. The evidence for this conclusion may be summarized as follows: first, the presence of a stipe is unknown in *Caulanthus* but is of common occurrence in *Thelypodium;* second, the inflorescence is more suggestive of the primitive species of *Thelypodium* or even of *Stanleya* than of any species of *Caulanthus;* third, its geographical position argues for its relationship to *Thelypodium* rather than to *Caulanthus;* finally, the entire stigma is common to all species of *Thelypodium* but is found only in the primitive species of *Caulanthus*, with which *C. hastata* does not agree in other respects. Only a few collections of *C. hastata* are known but it would appear that those individuals from Oregon possess a longer stipe than do those from Utah. If this prove to be true it would indicate that the Oregon form is the more primitive. Since it is in this region that the primitive species of *Thelypodium* occur this would argue for a common origin.

The question now arises as to the advisability of transferring this species to *Thelypodium* rather than keeping it up as a mono-

typic genus. The plant in question differs from all species of *Thelypodium* in the toothed petals and in the uniform septum. It has evidently given rise to no species now included in *Thelypodium* nor has it been derived from any species now extant. If it were placed in *Thelypodium* it would introduce an anomalous element into an otherwise homogeneous group. All things considered then, it seems best to retain *Chlorocrambe* as a unit distinct from either *Thelypodium* or *Caulanthus* but probably more closely related to the former than to the latter.

CAULANTHUS

The gynophore.—A slender stipe of one millimeter or more is not known in any species of *Caulanthus.* In some species, however, the pods are not quite sessile upon the torus. This short stipe, if such it may be called, is always thick and never comparable to that found in many species of *Thelypodium.* There is obviously but one conclusion to be drawn from this: if the long stipe is held to be a primitive character, then as a genus, *Caulanthus* is not so primitive as *Thelypodium.*

The pods.—In *Thelypodium* it was pointed out that those species which possessed long pods had preceded those with short pods in the sequence of development. An analysis of the length of the pods in *Caulanthus* shows a high degree of intra-specific variation and only in a very general way may the species be compared on this character. Because of the occurrence of long pods in species otherwise primitive and not because of any *a priori* argument it is believed that in *Caulanthus,* as in *Thelypodium,* long pods have preceded short ones in point of time.

With two exceptions the pods of this genus are practically terete. In *C. heterophyllus* they are somewhat compressed or quadrangular and in *C. californicus* the valves are slightly keeled. These species are evidently not closely related to one another nor may any developmental series be made by considering them primitive. They are obviously recent and more or less aberrant members of the genus.

Style and stigma.—In the majority of the species the style is very short and surmounted by a large stigma. The length of the style seems not to be constant for the species. One group of species, however, is characterized, in part, by the possession of a style that tapers appreciably from base to apex. This type has been described as "conic" in the key. This character reaches

its highest development in *C. lasiophyllus*, but even here it is trivial and serves rather for confirmation of relationship than as a definite diagnostic character. The small stigmas that terminate the styles of this type serve to emphasize this character.

The degree of lobing of the stigma is of considerable diagnostic value. Except in those species with conic styles, in which it is uniformly and minutely two-lobed, the stigma varies from entire to deeply two-lobed. In these species the lobing is invariably such that the lobes are produced over the valves. The lobes are always much more evident in the mature fruit than in the flower. This is perhaps due to the collapse of parenchymous tissue on drying and the consequent emphasizing of the vascular strands of the style. In the descriptions the length of the lobes of the stigma is derived from measurements in the fruit. It is believed that the entire stigma represents the primitive type and the degree of lobing is a measure of specialization. In *Thelypodium,* which is to be considered more primitive than *Caulanthus,* the stigma is almost universally entire. Those species of *Caulanthus* that are evidently aberrant and specialized—as *C. heterophyllus* and *C. californicus*—exhibit a definitely lobed stigma.

Septum.—The cell pattern of the septum in *Caulanthus* is quite uniform except for two or three species. It is thin and of short, mostly straight-walled cells of nearly equal breadth and length. This is in striking contrast to that of *Thelypodium* in which there is a highly differentiated middle band. The exceptions referred to occur in *C. anceps* and *C. lasiophyllus.* In the first species the cells are not unlike the normal type for the genus except that the walls are somewhat tortuous rather than straight. In the second the walls are tortuous and the middle region is differentiated as in *Thelypodium.* If one were to judge from the septum alone *C. lasiophyllus* would have to be retained in *Thelypodium* where it has previously been carried.

Seeds.—Few characters of taxonomic value are found in the seeds. In most of the species they are neither winged nor margined, and usually the cotyledons are somewhat oblique with respect to the radicle. This is the condition found in *Thelypodium* exactly. The relative position of the cotyledons and radicle is often quite variable. In *C. pilosus,* for instance, the position may vary greatly in seeds of the same individual. The most conspicuous exceptions to the usual structure are seen in *C. hetero-*

phyllus in which the seeds are narrowly winged and in *C. californicus* in which the cotyledons are deeply trifid.

The flowers.—The flower parts in *Caulanthus* offer more points of taxonomic and phylogenetic interest than they do for most of the genera of this family. The sepals may be nearly equal as in the majority of the species, or one pair may be definitely longer than the other, as in *C. Coulteri.* In many species they are more or less saccate, this character reaching its extreme in *C. californicus.* Species are now admitted to this genus with reduced, nearly flat sepals, and in one species, *C. anceps,* they are distinctly spreading.

The petals are equally diverse. In the great majority of the species they are narrow and crisped, with little differentiation between blade and claw. Petals of this type are usually channeled and curved outwards at the apex. In the past this type of petal was considered a generic character of *Caulanthus,* and species that did not show it were not included within the genus. In the present work, however, it has seemed impossible to exclude species with petals having plane blades and short claws.

In color the sepals and petals vary from purple to yellow, or the petals may be green in some species or individuals. An interesting change in color is noticed in the sepals of *C. Coulteri, C. Lemmonii,* and *C. californicus* as development proceeds. In the bud these organs are a deep purple but as the flower develops the color becomes paler until in the old blossom the purple color is scarcely evident.

The stamens of *C. inflatus, C. Coulteri, C. Lemmonii,* and *C. californicus* are of particular interest because of the frequent tendency of the two pairs of longer stamens to be more or less united by the filaments. This character serves not only to confirm the generic unity of *C. californicus* with *Coulteri* but furnishes evidence that the four long stamens have developed from two by multiplication of the anthers and filaments. The present cases would be considered partial reversions to an ancestral condition.

The phylogenetic sequence of the different types of floral structure becomes evident only by a correlation of these characters with the characters of the leaves, trichomes, pods, etc. Since the most primitive species possess a closed and slightly saccate calyx and narrow, crisped and channeled petals, it has been assumed that these types are primitive and that from them the other types have been evolved. It would seem that the flat,

oblanceolate type of petal has been developed four times within the genus, since it is found in *C. sulfureus, C. Cooperi, C. anceps,* and *C. lasiophyllus.* With the exception of the last two, these species are not closely related. The primitive color may have been purple.

Inflorescence.—The flower cluster in species of *Caulanthus* is, almost without exception, a lax raceme. The most interesting and significant detail of the inflorescence is to be found in the mature pedicels. In *C. Cooperi, C. simulans, C. heterophyllus,* and *C. stenocarpus* the pedicels are recurved and the pods deflexed. In *C. Coulteri, C. californicus, C. anceps,* and *C. lasiophyllus* the pedicels are either recurved or curved upwards and the pods in consequence are either deflexed or erect. With these species must be associated *C. Lemmonii* and *C. flavescens.* So far as is known the pods of these are always erect. This group of ten species is evidently closely related, to judge from other points of similarity, and is partially characterized by a tendency to develop recurved pedicels and deflexed pods. This character presents a strong argument for the retention of these ten species within one genus.

Leaves.—In ten species the cauline leaves are conspicuously amplexicaul by auriculate basal lobes. In eight they are either sessile or, usually, distinctly petioled; in neither case are the basal lobes developed. Three or four species have leaves that are nearly or quite entire. The leaves of the other fourteen or fifteen species are, in part at least, definitely toothed. In *Caulanthus* no such definite differentiation between radical and cauline leaves occurs as in *Thelypodium* but in most species the leaves near the base of the stem are usually longer, narrower, and more distinctly toothed than the upper stem-leaves. Since these basal leaves are often more closely crowded upon the stem than are the upper ones, there is an approximation to the rosette habit.

The inter-specific leaf variation seems to offer the best guide to the phylogenetic development within the genus. To judge from findings in *Thelypodium* the amplexicaul leaf would be considered primitive. Since this is the more usual form it is easier to examine those species with petioled than with clasping leaves. These are *C. glaucus, C. pilosus, C. Hallii, C. major, C. crassicaulis, C. flavescens, C. anceps,* and *C. lasiophyllus.* Five of these are species in which trichomes are developed. Two of the glabrous species, *C. major* and *C. crassicaulis,* are perennials. The first five species, and this includes the third glabrous

one, have definitely two-lobed stigmas. It will be recalled that the presence of trichomes, the assumption of the perennial habit, and the two-lobed stigmas are considered recent characters in this genus and in *Thelypodium*. It would seem then that the group of species with petioled stem-leaves is not primitive. This conclusion is strengthened by the evident fact that these eight species are not closely related forms but represent at least three different lines of development. They are interpreted as being at the ends of the several lines of evolution, and so it seems certain that the petioled leaf has been developed independently at least three times within the genus *Caulanthus*.

The transition between stem- and basal-leaves that occurs in some species of *Caulanthus* has already been referred to several times. In such a species as *C. heterophyllus*, for instance, may be seen a gradual transition from entire, amplexicaul upper stem-leaves to toothed, elongated, and non-clasping basal-leaves. This transition is believed to show the way in which the differentiation has occurred and to show that the basal-leaves have originated from the stem-leaves. It is significant that in the more primitive species, such as *C. amplexicaulis*, *C. inflatus*, and *C. Cooperi*, no differentiation is evident. It is also of interest to note that whenever trichomes are present they occur only at the base of the plant or are most numerous there. This basal region seems, therefore, in some way to retain fewer of the ancestral characters and to be the first to assume recent modifications.

Duration of life.—The species of *Caulanthus* are mostly annual. Two species only, *C. major* and *C. crassicaulis*, are short-lived perennials, although some of the annual species may approach the biennial habit. There seems to be, however, no true assumption of the biennial habit as in *Thelypodium*. Since the two perennial species may not be considered primitive for other reasons it is supposed that the annual condition is the more primitive.

GENERIC LIMITS OF CAULANTHUS

Caulanthus, as here treated, contains many more species than have been referred to it formerly and consequently embraces a greater range of morphological variation. These changes have made a formerly homogeneous group somewhat heterogeneous and have involved a number of nomenclatorial transfers. These two results are, in some ways, unfortunate but are inevitable if the present theory of development is correct and if classification

is to follow phylogenetic lines. The question of the generic disposition of the various species is, of course, a question of phylogeny.

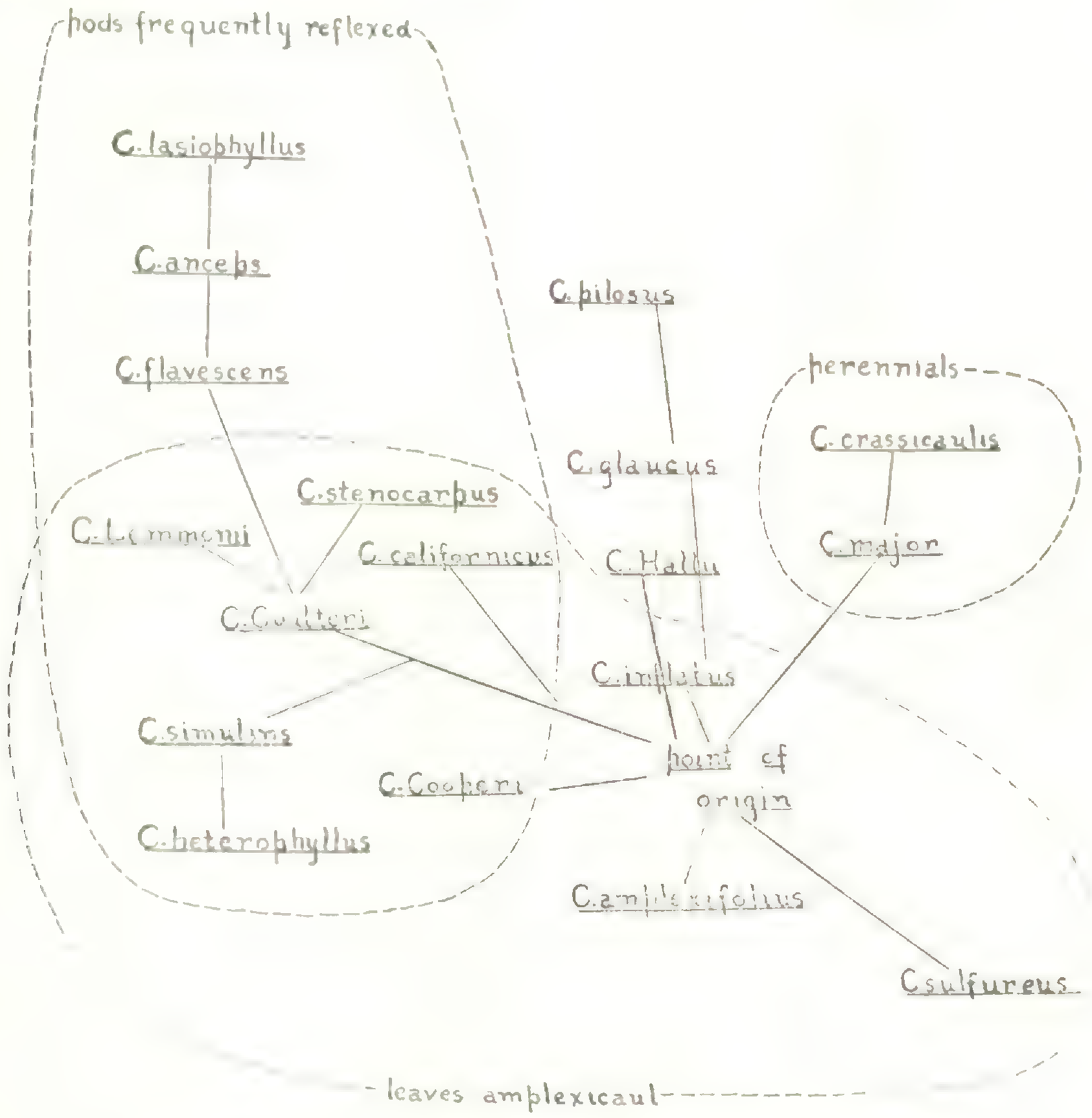

Fig. 2. Phylogenetic chart of the species of Caulanthus.

Guillenia.—Most interesting, in the light of the present generic limits of *Caulanthus*, is a consideration of those species designated by Dr. Greene as constituting a new genus—*Guillenia*. *Caulanthus lasiophyllus* was designated as the type of that genus, and with it and two of its varieties were associated *C. flavescens*, *C. Cooperi*, and *Streptanthella longirostris*. As will be seen by an examination of the phylogenetic chart of *Caulanthus* that accompanies this paper, *Guillenia* is a monophyletic group. Dr. Greene here united a group of closely related forms as a unit distinct from *Thelypodium*. *Guillenia* cannot be maintained under a broader generic concept and so becomes a part of the larger

group—*Caulanthus*. An exception must be made in the case of *Streptanthella longirostris* (*Guillenia rostrata* of Greene). Although probably derived from this group of species, it seems better to retain it as a separate genus than to transfer it to *Caulanthus*.

It is perhaps most difficult to appreciate the true generic position of *C. lasiophyllus*. If it were included in *Thelypodium* it would have to be associated with *T. laciniatum* on account of the form of the leaves since it does not resemble, even remotely, any other species. *T. laciniatum* is one of the most primitive species in the genus. If *lasiophyllus* were admitted to *Thelypodium* it would be considered one of the most highly specialized in several ways. The sessile pods, the corymbose inflorescence, and the numerous trichomes are recent characters. To have a highly specialized species developed from a very primitive one would be somewhat surprising since there would be no known intermediates. The annual habit of *lasiophyllus* does not accord with the usual biennial habit of *Thelypodium*. The recurved pedicels are also an aberrant character. From *Caulanthus* in the old, restricted sense, *C. lasiophyllus* is equally aberrant. If, however, the genus is enlarged to include *C. anceps* and *C. flavescens, C. lasiophyllus* does not seem out of place. *Caulanthus flavescens* has been known in *Caulanthus* for many years (as *C. procerus*) and has not been considered aberrant there. If this is admitted the inclusion of *lasiophyllus* is logical. Intermediate between *lasiophyllus* and *flavescens* is *C. anceps*. The three are evidently related and the differences are slight. *C. lasiophyllus* has a septum similar to that in *Thelypodium* but it has evidently been developed independently.

Stanfordia.—As pointed out elsewhere it is considered best to unite this monotypic genus with that group to which it is very certainly related. The single distinctive character it possesses (the trifid cotyledons) is not thought to be of sufficient importance to warrant its generic independence.

GEOGRAPHICAL DISTRIBUTION

Caulanthus is slightly more restricted in its distribution than is *Thelypodium*. Its species occur in the arid parts of western North America and chiefly between the Mexican boundary and the northern limits of California, Nevada, and Utah. One species, *C. lasiophyllus*, is known to occur in peninsular California

and has been reported also from as far north as Washington and as far east as Colorado. This species is the most widely distributed of the genus and has apparently spread as a weed along lines of transportation. Except for this species no members of the genus are known from Colorado.

Evidence at hand goes to show that *Caulanthus* originated in the interior region of southern California. Several reasons may be given for this belief: (1) In this region occurs the greatest number of species. (2) The most primitive species of the genus occur here. (3) The species at the greatest distance from this point are the most recent species phylogenetically.

SUMMARY OF CONCLUSIONS ON CAULANTHUS

1. Probably long, terete pods are to be considered primitive in *Caulanthus* and the shorter or compressed ones as derived.

2. The entire stigma is considered primitive and the degree of lobing is thought to be indicative of the degree of specialization. The most deeply lobed stigmas are found in those species that are most specialized in other respects. In *C. lasiophyllus* and its allies, however, this rule does not hold, since in this group the stigma is quite uniform and but slightly lobed.

3. The "cell pattern" of the septum is found to be of great importance as a generic character in *Caulanthus.* In *C. lasiophyllus* a type similar to that seen in *Thelypodium* is believed to have been independently developed.

4. The narrow, crisped and channeled type of petal is considered primitive for this genus. The flowers of the ancestral species were probably purple in color.

5. The most primitive type of inflorescence found in *Caulanthus* is lax and racemose.

6. Amplexicaul cauline leaves are believed to represent the primitive type and from them the petioled basal- or stem-leaves have been developed.

7. The presence of trichomes is an indication of specialization. They were probably not present in the first species of *Caulanthus.*

8. *Guillenia* of Greene could be maintained as a genus without offense to phylogeny but it is found inadvisable to separate it from *Caulanthus.*

9. The annual habit is held to be primitive.

10. *Stanfordia* of Watson is not thought worthy of generic rank and is merged with *Caulanthus.*

11. *Caulanthus* is believed to have originated in the interior region of southern California.

STREPTANTHELLA

The single, rather uniform species that constitutes this genus is an annual herb of comparatively wide distribution in the arid parts of western North America between the Sierra Nevada or coast ranges of California, Oregon, and Washington and the Rocky Mountains of Wyoming, Colorado, and New Mexico. It penetrates into the desert region of northwestern Mexico on the south but does not reach the Canadian boundary on the north. The species seems never to have crossed the Rocky Mountains.

The affinities of this plant have long been in doubt. As a member of *Arabis* it was evidently out of place. In *Streptanthus* it was somewhat less anomalous but was obviously not closely related to any known species of that genus. Dr. Greene seems to have been the first to associate it with its nearest relatives when he included it in *Guillenia*. It appears not to be very closely related to those species, however, and in the present treatment is not included with them in *Caulanthus*. The recurved pedicels give the strongest evidence of this relationship of *Streptanthella* to the *Guillenia* group of *Caulanthus*. The narrow, more or less crisped petals and the southwestern distribution of *S. longirostris* strengthen the argument that this species has been derived from the same stock as *C. Cooperi* and *C. lasiophyllus*. If this connection is not recognized then it must be admitted that no point of attachment is known between this species and other *Cruciferæ*. If this relationship is accepted the question arises as to the advisability of uniting *Streptanthella* with *Caulanthus* rather than maintaining it as a distinct genus.

Streptanthella has been maintained for several reasons. In the first place the relationship between it and *Caulanthus* can not be considered as proved. In the second place it is believed that the divergence from species of *Caulanthus* is sufficient to warrant generic segregation. The attenuation of the valves of the pod into a beak that simulates a style is a character unknown among the species of *Caulanthus*. The resulting type of dehiscence is peculiar. The valves, when dry, become free and curve away from the base but remain attached at the apex. The pods are more definitely compressed than in any species of *Caulanthus*. Since *Streptanthella* is thus not considered to be descended from those species of *Caulanthus* with flattened pods this character

must have been independently developed. The septum of *S. longirostris* is unlike that of any species of *Caulanthus*. There is here a differentiation of the middle cells. Those near the margin are elongated at right angles to the replum and are not tortuous. These give way toward the middle to cells that are somewhat tortuous and finally elongated parallel to the margin. The narrowly winged seeds indicate a development parallel to the condition in *C. heterophyllus*.

WAREA AND STANLEYELLA

Warea is a very homogeneous group of four species that occurs in the extreme southeastern part of the United States. Here they seem to be confined to sandy habitats. Their remarkable isolation from related species has undoubtedly been a factor in their universal retention within a single genus, since morphologically they are rather similar to species of *Stanleya* or *Stanleyella*. In general appearance they resemble certain species of *Capparidaceae* more closely than they do any other species of *Cruciferae*. Indeed the first species of *Warea* to be described was described as a *Cleome*.

Most of the characters of the species of *Warea* have been considered primitive in other genera. They are all annuals with erect, branching stems. The leaves are all entire and in one species they are deeply amplexicaul. Trichomes are not known to occur on any of the species. The petals vary in color from white to red-purple. The pedicels are straight and horizontally spreading although the inflorescence is definitely corymbose and does not elongate greatly even in fruit. The fruit is definitely stipitate, linear, and divaricate-falcate. The stigma is subentire.

All four species possess one character that serves to distinguish them from all related genera and, so far as the author knows, from all other species of *Cruciferae*. The pedicels in *Warea* are deciduous from the main axis of the inflorescence and fall away attached to the mature pods. Since the line of abscission is not quite even with the surface of the rachis there remains a small base attached to the stem. The presence of these remnants after the inflorescence has become quite mature gives a characteristic roughened or knobbed appearance to the axis. The mechanism by which this abscission occurs has not been thoroughly studied but, from sections made of the dried

material, seems to be due to a simple breaking apart of the cells in a certain region.

The septum in *Warea* is somewhat similar to that seen in *Thelypodium*. There is a differentiation between the cells near the margin and those in the middle. The latter are somewhat tortuous and considerably elongated. The walls are not densely compacted as in some species of *Thelypodium*.

That species which may be considered most primitive on account of the amplexicaul leaves occurs in eastern Florida. It does not, however, possess the longest stipe, although there is no considerable difference between the various species in the length of that organ. It is scarcely possible to trace any developmental sequence between the species that may be correlated with geographical distribution. This is of course partly due to the limited variation between the species and to their restricted range. *Warea Carteri* may well be an offshoot from *W. cuneifolia*.

Stanleyella is evidently most closely related to *Warea* but may be considered distinct from that genus because of the persistent pedicels, the much shorter stipe, and the different septum. The septum in *Stanleyella* is somewhat differentiated between margin and middle, but the cells are not tortuous as in *Warea*. The leaves in *Stanleyella* are toothed, while in *Warea* they are entire. Trichomes are present in some individuals of *Stanleyella* but have not been noticed in *Warea*. *Stanleyella* may be restricted to the southwestern and *Warea* to the southeastern portions of the United States. *Stanleyella* is undoubtedly to be considered less primitive than *Warea*, but because the absciss mechanism in the pedicels is lacking it was probably developed from a common ancestor and not from any of the present species of *Warea*.

Key to the Genera

The genera treated in the present paper may be contrasted and their chief morphological characters summarized by the following key. This key, it must be understood, makes no attempt to account for genera that are closely related but have not yet been elaborated.

A. Sepals spreading or reflexed in anthesis; glabrous or very sparsely pubescent, annual or biennial herbs; blade of petal entire; stigma entire or nearly so; pedicels slender, divaricate; pods widely spreading.
   a. Stipes 5 mm. or more long; leaves entire; pedicels becoming detached from the rachis at maturity----------WAREA

b. Stipes, if evident, not over 2 mm. long; leaves usually lobed; pedicels persistent ---------- STANLEYELLA

B. Sepals erect or connivent, except in a few species; glabrous to conspicuously pubescent, annual, biennial or perennial herbs; blade of petals entire or toothed; stigma entire or 2-lobed; pedicels various; pods erect, divaricate or reflexed.

a. Pods frequently stipitate; biennial or perennial herbs; petals flat, entire or toothed; pedicels never strongly recurved; stigmas entire.

I. Petals entire, purple, white, or blue; septum differentiated in the middle; leaves, except in one species and its varieties, entire ---------- THELYPODIUM

II. Petals toothed, white or greenish white; septum nearly uniform; leaves petioled and irregularly margined ---------- CHLOROCRAMBE

b. Pods sessile or subsessile on a very broad stipe; annual or perennial herbs; petals entire, flat, or channeled and then usually crisped and narrow; pedicels various, frequently recurved; stigmas entire or 2-lobed.

I. Valves of the pod separating from the replum at maturity, rarely strongly flattened; stigmas entire or 2-lobed; pedicels various ---------- CAULANTHUS

II. Valves of the pod produced into a beak at the apex and at maturity separating from the replum only at the base, strongly flattened; stigmas entire; pedicels recurved ---------- STREPTANTHELLA

Taxonomy

Taxonomic History of the Several Genera

Thelypodium and Stanleyella.—The first species of *Thelypodium* to be described was *T. laciniatum*. W. J. Hooker studied this plant from material collected by Douglas and referred it to *Macropodium* in 1830. In 1838, Torrey and Gray recognized it as generically distinct from that genus and published the genus *Pachypodium* from Nuttall's manuscript. Besides *laciniatum* there were now referred to *Pachypodium* two other species, *integrifolium* and *sagittatum*. The choice of the name *Pachypodium* was an unfortunate one because of the previously published genus of the same name by Lindley (1830) in the *Apocynaceae* as well as the *Pachypodium* of Webb and Berthelot (1836-1840). This latter genus was based on a cruciferous plant now generally assigned to *Sisymbrium* (*S. erysimioides* Desf.). In 1839 Endlicher proposed the name *Thelypodium* to replace the untenable *Pachypodium* of Nuttall. This first publication gives only a description with a reference to the genus proposed by Nuttall which *Thelypodium* was to replace. In Walpers' 'Repertorium' (1842) the name *Thelypodium* was again taken up and to it were assigned three species—*T. laciniatum, T. integrifolium,*

and *T. sagittatum*. At this time, then, the name *Thelypodium* was definitely established to replace the unfortunate name of *Pachypodium* as used by Nuttall. The genus was, of course, considered distinct from *Macropodium*.

From 1842 until 1907 the number of species assigned to *Thelypodium* gradually increased. In 1852 Dr. Gray added the first anomalous element as *T. Wrightii*—now *Stanleyella Wrightii*. After this, *Thelypodium* became a receptacle for many plants which, on account of their entire stigmas, were not admitted to *Sisymbrium*. Dr. Watson transferred a number of species to *Thelypodium* which had originally been described as species of *Streptanthus* or *Sisymbrium*. In 1895 there appeared in the 'Synoptical Flora' an excellent treatment of *Thelypodium* in the larger sense by Dr. Robinson. In this treatment the diversity of the species retained is recognized and sections are proposed to contain the more different groups.

The first attempt at segregation was made in 1907 when Dr. Rydberg separated from this *Thelypodium* complex the new genera *Thelypodiopsis, Pleurophragma, Hesperidanthus, Stanleyella,* and *Heterothrix*. In the present study *Pleurophragma* is again united to *Thelypodium,* and *Stanleyella* is recognized as a distinct genus. No disposition of the other segregates is made at the present time except that they are not to be retained in *Thelypodium*.

Caulanthus and Chlorocrambe.—Watson in 1871 proposed the genus *Caulanthus* to include five species of *Cruciferae* from western North America. Of these five, two were described as new and three were transferred from *Streptanthus*. The first species mentioned and the one on which the genus was evidently founded is *C. crassicaulis* (*Streptanthus crassicaulis*). This species not only agrees more closely with the generic description than do the others but in a note following the specific description this explanation of the new generic name is given: "known as 'Wild Cabbage', and sometimes used as a tolerable substitute for the cultivated plant. This fancied affinity to the Cauliflower-tribe of more favored regions has suggested the generic name." This species then would, without doubt, become the generic type if the group were segregated. Only one species of the five included in the original treatment of the genus is not now considered congeneric with the others, *C. hastatus*. Following the publication of *Caulanthus* a few species were added from time to time and the validity of the genus was almost universally accepted. As

in *Thelypodium* the most extended account of *Caulanthus* previously published was by Dr. Robinson in the 'Synoptical Flora.' In this work nine species were recognized. In the present treatment the author has found it necessary to transfer to *Caulanthus* several species carried for many years in other genera as well as to describe a few new species. Accordingly the number of species has been increased and the limits of intrageneric diversity greatly extended.

The only segregation of *Caulanthus* in its former limited sense that has ever been attempted was the removal by Dr. Rydberg in 1907 of *C. hastatus* as the type of the monotypic genus *Chlorocrambe.*

Streptanthella.—Dr. Rydberg in 1917 proposed this monotypic genus to contain a species of uncertain affinities. This plant was first described by Watson as *Arabis longirostris* in 1871 but in 1889 was transferred by the same author to *Streptanthus* and has been generally treated in that genus up to the present time. In 1906 Greene included this species in his genus *Guillenia* as *G. rostrata.*

Warea.—The similarity of species of this genus to certain capparidaceous plants was recognized by Muhlenberg who in 1813 proposed the name (without description) *Cleome cuneifolia* for the plant now known as *Warea cuneifolia.* However, it was soon recognized that its affinities were with the *Cruciferae* rather than with the *Capparidaceae.* DeCandolle in 1821 independently described *cuneifolia* as *Stanleya gracilis* and Nuttall in 1822 published *amplexifolia* as a *Stanleya.* It was in 1834 that Nuttall reconsidered this disposition of these plants and erected the genus *Warea,* named in honor of Nathaniel A. Ware, to receive them. Nuttall recognized but two species although it seems evident that he had three at hand, and that he based the genus primarily upon his earlier *Stanleya amplexifolia.* Since that time the validity of the genus has not been questioned and but two species have been added to it.

THELYPODIUM

THELYPODIUM Endl. Gen. 876. 1839; Walp. Rep. 1: 172. 1842; Wats. Bot. King's Exp. 25. 1871, in part; Brewer & Wats. Geol. Survey Calif. Bot. 1: 37. 1876, in part; Prantl in Engler & Prantl, Nat. Pflanzenfam. III. Abt. 2: 155. 1891; Robinson in Gray, Syn. Fl. N. Am. 1[1]: 173. 1895, in part; Nelson in Coulter &

Nelson, Manual Cent. Rocky Mountains, 209. 1909, in part; Hayek, Beih. Bot. Centralbl. 27[1]: 184. 1911; Rydb. Fl. Rocky Mountains, 366. 1917, in part.

Macropodium Hook. Bot. Misc. 1: 341. 1832, in part; Hook. Fl. Bor. Am. 1: 43. 1840, not R. Br.

Pachypodium Nutt. in Torr. & Gray, Fl. N. Am. 1: 96. 1838, not Webb & Berthel.; Benth. & Hook. f. Gen. Pl. 1: 81. 1862.

Pleurophragma Rydb. Bull. Torr. Bot. Club 34: 433. 1907; Wooton & Standley, Contr. U. S. Nat. Herb. 19: 267. 1915; Rydb. Fl. Rocky Mountains, 368. 1917.

Biennial or perennial herbs with differentiated radical and cauline leaves and usually erect, simple or branched stems. Trichomes absent or unbranched. Stem-leaves frequently sagittate at the base. Flowers purple, lilac, roseate or white; sepals scarcely if at all saccate; petals linear, oblong or oblanceolate, entire; anthers frequently apiculate. Inflorescence usually racemose, rarely corymbose. Pods terete or slightly flattened parallel to the partition, distinctly stipitate or sessile, 1.5–10 cm. long, 1–2 mm. wide, horizontal to erect; style short, stigma small, entire or very slightly 2-lobed. Cells of the septum elongated parallel to the replum in the middle, usually more or less tortuous, shorter, and walls usually less closely compacted near the margin; this central region of elongated cells frequently appears under a hand lens as a broad midvein. Seeds not winged, cotyledons usually obliquely incumbent. Generic type: *T. laciniatum* (Hook.) Endl.

Key to the Species

A. Cauline leaves sagittate or amplexicaul at the base.
  a. Stipe about 2 mm. long; flowers red-purple; inflorescence dense, racemose, pedicels horizontal ---------- *1. T. eucosum*
  b. Stipe usually less than 2 mm. long.
    I. Biennials or short-lived perennials.
      *Raceme dense, narrow, spike-like; pedicels rarely over 5 mm. long.
        1. Pedicels stout, divergent, 1–2 mm. long ---------- *2. T. brachycarpum*
        2. Pedicels slender, erect, 3–5 mm. long *3. T. crispum*
      **Raceme lax and narrow or, if dense, corymbose and broader; pedicels usually more than 5 mm. long.
        1. Petals spatulate or broader.
          0. Inflorescence distinctly racemose.
            x. Radical leaves lyrately toothed; plants native to Oregon and California --- *4. T. Howellii*
            y. Radical leaves entire; plants native to Utah, Arizona and New Mexico.

†Pods 1–3 cm. long ----- *5. T. ovalifolium*
††Pods 4–6 cm. long------ *6. T. vernale*
00. Inflorescence corymbose or shortly racemose.
x. Pods 1–1.5 mm. wide ------ *7. T. sagittatum*
y. Pods about 2 mm. wide---- *7a. T. sagittatum* var. *crassicarpum*

2. Petals filiform; inflorescence racemose from before anthesis-------- *8. T. stenopetalum*

II. Perennial; caudex clothed with the papery leaf bases of previous years' growth-------- *9. T. flexuosum*

B. Cauline leaves not sagittate or amplexicaul at the base.
a. Leaves toothed or lobed.
I. Pedicels horizontal; pods widely spreading.
*Sepals white ---------- *10. T. laciniatum*
**Sepals purple, at least in part --------- *10a. T. laciniatum* var. *streptanthoides*
II. Pedicels curved upwards; pods erect or nearly so ---------- *10b. T. laciniatum* var. *milleflorum*
b. Leaves entire.
I. Pedicels 3–5 mm. long, flattened at the base, petals white.
*Stipe 1–2 mm. long ---------- *11. T. rhomboideum*
**Stipe 2–3 mm. long ---------- *11a. T. rhomboideum* var. *gracilipes*
II. Pedicels 5–10 mm. long; petals white or purple.
*Stipe 1–2 mm. long; nectar glands horn-like processes.
1. Nectar glands 4; pods terete ------ *12. T. integrifolium*
2. Nectar glands 2 (lateral pairs coherent); pods somewhat compressed--- *13. T. affine*
**Stipe usually less than 1 mm. long; nectar glands inconspicuous, low.
1. Mature inflorescence elongated------ *14. T. lilacinum*
2. Mature inflorescence subumbellate--- *14a. T. lilacinum* var. *subumbellatum*

1. T. eucosum Robinson in Gray, Syn. Fl. N. Am. 1[1]: 175. 1895; Howell, Fl. Northwest Am. 58. 1897; Frye & Rigg, Northwest Fl. 179. 1912; Rydb. Fl. Rocky Mountains, 367. 1917.

T. Nuttallii Brewer & Wats. Geol. Survey Calif. Bot. 1: 37. 1876, in part.

Probably biennial, glabrous throughout, more or less glaucous: radical leaves oblanceolate, narrowed to a petiole, subentire; cauline leaves oblong to lanceolate, entire, 2–6 cm. long, usually acute, amplexicaul at the base: sepals reddish purple, narrow, 6–7 mm. long, not saccate; petals narrowly spatulate, 8–11 mm. long, red-purple; filaments linear, 6–7 mm. long, purplish, anthers about 3 mm. long, apiculate: inflorescence racemose; pedicels horizontal or slightly descending, enlarged at the apex, 3–5 mm. long: pods arcuate, ascending, terete, slightly torulose, 3–4.5 cm. long (not mature); stipe about 2 mm. long; style less than 1 mm. long; stigma entire, small.

Distribution: eastern Oregon. Type: *Nevius* from Baker City.

Specimens examined:

Oregon: Blue Mountains, May 21, 1885, *Howell 345* (Gray Herb.); Baker City, 1875, *Nevius* (Gray Herb., TYPE).

A very beautiful and quite distinct species that has been collected but seldom. Because of its striking appearance this scarcity in herbaria must indicate a very limited range or infrequent occurrence.

2. T. brachycarpum Torr. U. S. Expl. Exp. **17**: 231, *t. 1.* 1874; Wats. Bot. King's Exp. 26. 1871, in part; Brewer & Wats. Geol. Survey Calif. Bot. **1**: 37. 1876, in part; Robinson in Gray, Syn. Fl. N. Am. **1**[1]: 174. 1895, in part.

Biennial, glabrous or sparsely pilose towards the base: stems 3–15 dm. high, simple or virgately branched, usually stout: radical leaves oblanceolate or spatulate, definitely toothed to deeply lyrate-pinnatifid, 4–6 cm. long; cauline leaves 1–5 cm. long, narrow, acute, entire or toothed, sagittate at the base and sessile, basal lobes acute: sepals and petals white, the former linear-lanceolate, acute, the latter linear, 2–3 times as long as the sepals; stamens exserted, filaments nearly equal, anthers nearly 2 mm. long, distinctly sagittate at the base, apiculate: inflorescence dense, racemose; pedicels stout, 1–2 mm. long, divergent: pods unequally torulose, ascending, 15–30 mm. long; stipe 1–1.5 mm. long; style about 0.5 mm. long, stigma truncate, small; seeds not winged.

Distribution: southern Oregon and northern California. Type: *Wilkes' Expedition* "on the Klamet River, southern borders of Oregon."

Specimens examined:

California: near Yreka, Siskiyou County, June 11, 1876, *Greene 846* (Mo. Bot. Gard. Herb.); 6,300 ft. altitude, Scott's Mountain, Aug. 29, 1880, *Engelmann* (Mo. Bot. Gard. Herb.); north side of Mt. Shasta, June 15–30, 1897, *Brown 469* (Mo. Bot. Gard. Herb.); Shasta Valley, June, 1903, *Hall & Babcock 4092* (Mo. Bot. Gard. Herb. and Univ. Calif. Herb.); Montague, June 9, 1905, *Heller 8011* (Mo. Bot. Gard. Herb.); Shasta Valley, Aug. 21, 1910, *Butler 1850* (Univ. Calif. Herb.).

True *T. brachycarpum* is not so common a plant as formerly supposed. Most of the material that has previously been referred here is now assigned to *T. crispum*. The original drawing of this

species together with the station from which the type was obtained is sufficient to establish its identity.

3. T. crispum Greene, n. sp.[1]

T. brachycarpum Gray, Proc. Am. Acad. 6: 520. 1866, not Torr.; Wats. Bot. King's Exp. 26. 1871, in part; Brewer & Wats. Geol. Survey Calif. Bot. 1: 37. 1876, in part; Greene, Fl. Franciscana, 262. 1891; Robinson in Gray, Syn. Fl. N. Am. 1[1]: 174. 1895, in part.

Biennial, glabrous or sparingly pilose towards the base: stems 3–8 dm. high, simple or virgately branched: radical leaves oblanceolate or spatulate, nearly entire to deeply lyrate, 4–6 cm. long; cauline leaves 1–5 cm. long, linear-sagittate, acute, sessile, entire or shallowly repand, basal lobes acute: sepals and petals white (the former occasionally purple), the latter linear-spatulate, about twice as long as the sepals; stamens exserted, filaments nearly equal, anthers 2.5–3 mm. long, apiculate, sagittate at the base: inflorescence dense, racemose; pedicels slender, 3–5 mm. long, erect: pods unequally torulose, 1.5–3 cm. long; stipe about 1 mm. long; style 0.5–1 mm. long, stigma small, truncate.

Distribution: western Nevada and adjacent California.

Specimens examined:

Nevada: Lake Washoe, 1865, *Torrey 14* (Mo. Bot. Gard. Herb.); Empire City, June 19, 1882, *Jones 3769* (Mo. Bot. Gard. Herb. and Clokey Herb.); Washoe Lake, June 3, 1897, *Jones* (Mo. Bot. Gard. Herb.); Eagle Valley, Ormsby County, June 28, 1902, *Baker 1191* (Rky. Mt. Herb. and Mo. Bot. Gard. Herb., TYPE); King's Canyon, Ormsby County, July 30–Aug. 1, 1902, *Baker 1218* (Rky. Mt. Herb. and Mo. Bot. Gard. Herb.).

California: 1875, *Lemmon* (Mo. Bot. Gard. Herb.); Dixey Valley, Lassen County, July 6, 1894, *Baker & Nutting* (Univ. Calif. Herb.); Milford, June 26, 1892, *Brandegee* (Univ. Calif. Herb.); Sierra County, 1874, *Lemmon 12* (Mo. Bot. Gard. Herb.); Sierra County, 1875, *Lemmon 24* (Mo. Bot. Gard. Herb.); Sierra County, July, 1892, *Sonne 337* (Mo. Bot. Gard.

[1]**Thelypodium crispum** Greene, sp. nov., bienne glabrum vel basi pilosum; caule 3–8 dm. alto simplice vel ramoso, ramis strictis; foliis radicalibus oblanceolatis subintegris vel lyratis 4–6 cm. longis; foliis caulinis 1–5 cm. longis linearisagittatis acutis sessilibus amplexicaulibus integris vel repandis; sepalis petalisque albis, petalis lineari-spatulatis, staminibus exsertis; inflorescentiis dense racemosis, pedicellis gracilibus erectis 3–5 mm. longis; siliquis torulosis erectis 1.5–3 cm. longis, stipite circiter 1 mm. longo, stylo 0.5–1 mm. longo, stigmate parvo integro. —Collected in Eagle Valley, Ormsby County, Nevada, June 28, 1902, *Baker 1191* (Rky. Mt. Herb. and Mo. Bot. Gard. Herb., TYPE).

Herb.); Sierra County, July, 1894, *Sonne* (Univ. Calif. Herb.); Purdy, July 1, 1907, *Heller & Kennedy 8671* (Mo. Bot. Gard. Herb. and Univ. Calif. Herb.); McFarland's mill, Placer County, July 11 ,1886, *Sonne* (Univ. Calif. Herb.); Mono Pass, 1866, *Bolander 6272* (Mo. Bot. Gard. Herb.); Bloody Canyon, Mono County, July 20, 1889, *Chestnut & Drew* (Univ. Calif. Herb.); meadows at Bishop, Inyo County, June 1, 1906, *Hall & Chandler 7284* (Univ. Calif. Herb.).

Herbarium specimens labelled "*T. crispum* Greene," a name that has apparently never been published, serve as the type of a new species definitely distinct from *T. brachycarpum* by the slender, erect pedicels.

4. T. Howellii Wats. Proc. Am. Acad. **21**: 445. 1886; Robinson in Gray, Syn. Fl. N. Am. 1^1: 174. 1895; Howell, Fl. Northwest Am. 58. 1897; Frye & Rigg, Northwest Flora, 179. 1912.

Streptanthus Howellii Jones, Proc. Calif. Acad. II. **5**: 623. 1895.

Thelypodium simplex Greene, Pittonia **4**: 200. 1900.

Biennial, more or less hispid-pubescent near the base, otherwise glabrous, somewhat glaucous: stems slender, erect, simple or branched at the base, sparingly branched above, 3–8 dm. high: radical leaves rosulate, oblanceolate, obtuse, lyrately toothed, 2–4 cm. long; cauline leaves entire, lance-linear, acute, erect and usually appressed, sagittate at the base, sessile, 1–4 cm. long: sepals usually purplish, lateral somewhat saccate at the base, scarious margined, about 7 mm. long; petals pale blue or purple, spatulate, crisped, twice as long as the sepals; stamens slightly longer than the sepals: inflorescence racemose, lax; pedicels ascending, about 5 mm. long, stout: pods erect or ascending, 2–5 cm. long, about 1 mm. wide; stipe less than 0.5 mm. long; style about 1 mm. long, stigma entire; septum uniformly colored.

Distribution: eastern Oregon and northeastern California. Type: *T. Howell* from "Camp Polk and in Harney Valley, eastern Oregon."

Specimens examined:

Washington: 1883, *Brandegee 638* (Univ. Calif. Herb.).

Oregon: Yanex Reservation, July, 1893, *Austin* (Univ. Calif. Herb. and Mo. Bot. Gard. Herb.); wet soil, Farewell Bend, Crook County, July 16, 1894, *Leiberg 455* (Mo. Bot. Gard. Herb.); wet meadow, Camp Polk, June 14, 1902, *Cusick 2812*

(Univ. Calif. Herb. and Mo. Bot. Gard. Herb.); moist, subalkaline soil of Silver Creek, Aug. 8, 1901, *Cusick 2735* (Univ. Calif. Herb., Mo. Bot. Gard. Herb., and Rky. Mt. Herb.); dry alkaline meadows, eastern Oregon, June, 1897, *Cusick 1618* (Univ. Calif. Herb. and Mo. Bot. Gard. Herb.).

California: Big Valley, Modoc County, June 29, 1894, *Baker & Nutting* (Univ. Calif. Herb.); adobe meadows, Dixey Valley, Lassen County, July 6, 1894, *Baker & Nutting* (Univ. Calif. Herb.).

5. T. ovalifolium Rydb. Bull. Torr. Bot. Club 30: 253. 1903; Rydb. Fl. Rocky Mountains, 367. 1917.

T. Palmeri Rydb. Bull. Torr. Bot. Club 34: 432. 1907; Rydb. Fl. Rocky Mountains, 367. 1917.

Biennial or short-lived perennial, glabrous or sparsely hirsute below: stems several from the base, rather slender, decumbent, simple or sparingly branched, 3–6 dm. high: radical leaves somewhat rosulate, outermost broadly oblanceolate, about 2 cm. long, later ones 5–7 cm. long, narrowly oblanceolate or with a broadly oval blade, abruptly narrowed to a slender petiole, petioles more or less ciliate; cauline leaves sagittate, erect, about 2 cm. long: sepals oblong, about 4 mm. long; petals spatulate, about 7 mm. long: inflorescence narrow, racemose, elongated and rather lax when mature; pedicels ascending, rather stout, 4–6 mm. long: pods ascending or erect, somewhat torulose, subsessile, 1.5–3 cm. long, 1 mm. wide; style 1–2 mm. long, stigma small, entire; septum similar to that of *T. sagittatum*.

Distribution: southern Utah. Type: *M. E. Jones 6015e* from Panguitch Lake.

Specimens examined:

Utah: Panguitch Lake, Sept. 7, 1894, *Jones 6015e* (U. S. Nat. Herb., TYPE); southern Utah, 1877, *Palmer 25* (Mo. Bot. Gard. Herb.).

Although insufficiently known, it seems evident on comparison of type material of *T. ovalifolium* and *T. Palmeri* that but one species is represented. In the former the pods are 1–2.5 cm. long and the basal leaves are nearly glabrous except for ciliations on the petioles; in the latter the pods are 1.5–3 cm. long and the basal leaves sparsely hirsute. Only two collections are known and these evidently came from localities not far separated since the type of *T. Palmeri* was from "southern Utah." The differences are so slight and the habital resemblance is so great that these

plants must be considered conspecific, at least until further collections confirm their segregation.

6. T. vernale Wooton & Standley, Contr. U. S. Nat. Herb. **16**: 128. 1913, and **19**: 268. 1915.

Biennial, glabrous: stems slender, branched throughout, glaucous, purplish near the base, about 4 dm. high, the branches strongly ascending: cauline leaves triangular-lanceolate, attenuate, 3.5–5 cm. long, slightly glaucous, entire, somewhat undulate, auriculate-clasping at the base, the lobes obtuse, 5–7 mm. long: sepals narrowly oblong, obtuse, 2.5 mm. long, green or tinged with purple; petals white, slightly tinged with purple, narrowly oblong, tapering gradually toward the base, the whole 5 mm. long or less: racemes elongated; pedicels ascending, slender, about 5 mm. long: pods slender, 4–6 cm. long, somewhat divergent, arcuate; septum without a midrib; style truncate, stigma not bilobate.

Distribution: western New Mexico. Type: *Wooton 3847* from "low mountains west of San Antonio, Socorro County."

No specimens have been seen that could be referred to this species and its identity remains in doubt. From a geographical viewpoint it might be supposed to be most closely related to *T. ovalifolium* but the very long pods seem to distinguish it from that species.

7. T. sagittatum (Nutt.) Endl. in Walp. Rep. **1**: 172. 1842; Wats. Bot. King's Exp. 25. 1871; Brewer & Wats. Geol. Survey Calif. Bot. **1**: 37. 1876; Coulter, Manual Rocky Mountain Region, 21. 1885; Robinson in Gray, Syn. Fl. N. Am. 1^1: 175. 1895; Clements & Clements, Rocky Mountain Flowers, 28. 1914; Rydb. Fl. Rocky Mountains, 367. 1917.

Streptanthus sagittatus Nutt. Jour. Acad. Phila. **7**: 12. 1834; Torr. & Gray, Fl. N. Am. **1**: 76. 1838; Hook. & Arn. Bot. Beechey's Voy. 322. 1841; Walp. Rep. **1**: 128. 1842; Dietr. Syn. Pl. **3**: 729. 1843; Gray, Proc. Am. Acad. **6**: 187. 1866.

Pachypodium sagittatum Nutt. in Torr. & Gray, Fl. N. Am. **1**: 97. 1838; Dietr. Syn. Pl. **3**: 702. 1843.

Thelypodium Nuttallii Wats. Bot. King's Exp. 26. 1871; Coulter, Manual Rocky Mountain Region, 21. 1885; Robinson in Gray, Syn. Fl. N. Am. 1^1: 176. 1895; Howell, Fl. Northwest Am. 58. 1897; Rydb. Fl. Rocky Mountains, 367. 1917.

?T. amplifolium Greene, Erythea **4**: 173. 1896.

T. sagittatum Heller, Bull. Torr. Bot. Club 25: 265. 1898; Piper, Contr. U. S. Nat. Herb. 11: 298. 1906; Frye & Rigg, Northwest Fl. 179. 1912.

T. torulosum Heller, Bull. Torr. Bot. Club 25: 265. 1898; Nelson in Coulter & Nelson, Manual Cent. Rocky Mountains, 210. 1909; Frye & Rigg, Northwest Fl. 179. 1912; Garrett, Spring Fl. Wasatch Region, 48. 1912; Armstrong, Field Book Western Wild Flowers, 176, *fig.* 1915.

T. paniculatum A. Nelson, Bull. Torr. Bot. Club 26: 126. 1899; Rydb. Fl. Colo. 167. 1906; Nelson in Coulter & Nelson, Manual Cent. Rocky Mountains, 210. 1909; Daniels, Fl. Boulder, Colo. 135. 1911.

T. macropetalum Rydb. Bull. Torr. Bot. Club 29: 233. 1902; Rydb. Fl. Rocky Mountains, 367. 1917.

Biennial or short-lived perennial, glaucous, glabrous or sparsely hirsute near the base: stems usually branched from the base as well as upwards, erect or ascending, 3–7 dm. high: radical and lowermost cauline leaves entire, oblanceolate, 4–12 cm. long; stem-leaves ovate-lanceolate or narrower, auriculate at the base with broad lobes, usually acute: sepals purplish with scarious margins, not saccate at the base, somewhat unequal, 5–7 mm. long; petals white to deep purple, 2–3 times as long as the sepals, blade oblanceolate, gradually narrowed to the slender claw which nearly equals it in length; filaments 4–7 mm. long, anthers apiculate, about 2 mm. long: inflorescence corymbose, elongating and racemose when mature; pedicels divergent-ascending, nearly straight, enlarged at the apex, 5–12 mm. long: pods erect or strongly ascending, slender, frequently somewhat torulose, subsessile, 3–6 cm. long; style 1–1.5 mm. long, stigma entire: seeds irregularly angled, cotyledons obliquely accumbent.

Distribution: southwestern Wyoming, northern Colorado, southern Idaho, Utah, and northern Nevada. Type: *Wyeth* "on the banks of the Little Goddin River towards the sources of the Columbia." This is now known as the Little Lost River of Idaho.

Specimens examined:

Wyoming: Wheatland, June 18, 1891, *Nelson 58* (Rky. Mt. Herb.); saline flats, Kemmerer, June 13, 1900, *Nelson 7164* (Rky. Mt. Herb.); Fossil, June 12, 1898, *Nelson 4673* (Rky. Mt. Herb. and Mo. Bot. Gard. Herb.); Evanston, May 29, 1897, *Nelson 3013* (Rky. Mt. Herb.); Evanston, June 5, 1898, *Nelson 4545* (Rky. Mt. Herb.).

Colorado: Camp Creek, Larimer County, July 6, 1903, *Goodding 1466* (Rky. Mt. Herb. and Mo. Bot. Gard. Herb.); Grizzly Creek, July 24, 1896, *Baker* (Mo. Bot. Gard. Herb.).

Idaho: Soda Springs, June 21, 1892, *Mulford* (Mo. Bot. Gard. Herb.); Ketchum, June 24, 1892, *Mulford* (Mo. Bot. Gard. Herb.); Ketchum and Guyer Hot Springs, July 22, 1911, *Nelson & Macbride 1346* (Rky. Mt. Herb.); Picabo, July 1, 1916, *Macbride & Payson 2982* (Rky. Mt. Herb. and Mo. Bot. Gard. Herb.); Hailey, Wood River, July 22, 1895, *Henderson 3248* (U. S. Nat. Herb.).

Utah: Logan, April 18, 1909, *Smith 1529* (Rky. Mt. Herb.); Logan, June 13, 1909, *Smith 1640* (Rky. Mt. Herb.); Brigham, Box Elder County, May 9, 1910, *Smith 2121* (Rky. Mt. Herb.); Stansbury Island, June 18, 1883, *Leonard* (Univ. Calif. Herb.); Juab, June 10, 1902, *Goodding 1085* (Mo. Bot. Gard. Herb. and Rky. Mt. Herb.).

Nevada: O'Neil, July 18, 1912, *Nelson & Macbride 2085* (Mo. Bot. Gard. Herb. and Rky. Mt. Herb.); Palisade, June 14, 1882, *Jones 3768* (Mo. Bot. Gard. Herb. and Clokey Herb.).

7a. Var. crassicarpum Payson, n. var.[1]

T. sagittatum Nelson, First Rept. Fl. Wyo. 205. 1896, as to specimens cited, not Endl.

T. torulosum Rydb. Mem. N. Y. Bot. Gard. 1: 171. 1900, not Heller.

Biennial, glaucous, very sparsely hirsute near the base: stems rather stout, erect, branching upwards: radical leaves entire, oblanceolate; cauline leaves auriculate at the base, usually obtuse at the apex: inflorescence corymbose; pedicels rather stout, 5–8 mm. long, divergent: pods 2–3.5 cm. long, stout, nearly 2 mm. in diameter.

Distribution: western Montana, northwestern Wyoming; Washington.

Specimens examined:

Montana: Alaska Basin, Madison County, June 20, 1899, *Nelson & Nelson 5474* (Rky. Mt. Herb. and Mo. Bot. Gard. Herb.).

Wyoming: Yellowstone Nat. Park, Aug. 5, 1885, *Letterman 13* (Mo. Bot. Gard. Herb.); Yellowstone Canyon, Aug. 24, 1899,

[1] **Thelypodium sagittatum** (Nutt.) Endl. var. **crassicarpum** var. nov., bienne; siliquis 2–3.5 cm. longis, crassis, 2 mm. latis.—Collected in Yellowstone Canyon, Wyoming, Aug. 24, 1899, *Aven Nelson & Elias Nelson 6663* (Mo. Bot. Gard. Herb., TYPE).

Nelson & Nelson 6663 (Rky. Mt. Herb. and Mo. Bot. Gard. Herb., TYPE); Jackson's Hole on Snake River, June 15, 1860, *Hayden* (Mo. Bot. Gard. Herb.); Bacon Creek, Uinta County, Aug. 15, 1894, *Nelson 922* (Mo. Bot. Gard. Herb. and Rky. Mt. Herb.).

Washington: 1889, *Vasey 194* (U. S. Nat. Herb.).

Much of the confusion and the involved synonymy that has obtained in regard to this species has been due to the effort to maintain *Streptanthus sagittatus* and *Pachypodium sagittatum* of Nuttall as distinct. It is altogether possible that Nuttall himself may not have regarded them as different and the confusion may have arisen because of a change in Nuttall's opinion as to the genus to which the species should be referred. The type of *S. sagittatus* was collected by Wyeth in 1833 on the "Little Goddin River" and of *P. sagittatum* presumably by Nuttall on "Plains on the west side of the Rocky Mountains" in 1834. The types are so fragmentary and immature as to make identification doubtful.

After a study of a considerable series of specimens it was found impossible to maintain as distinct the various segregates of this species recently proposed. Only two forms seem to stand out as separable—a southern one with slender pods and a northern one with thick pods. When mature these plants are easily separated and no intermediates have been seen; their ranges also seem to be constantly distinct. With the species thus limited the question arose as to the exact location from which the type specimens were secured. Nuttall on his trip to Oregon with Wyeth in 1834 followed the famous "Oregon Trail" and from the journal kept by Dr. Townsend, another member of the party, it seems certain that nowhere did they go far enough north to encounter the variety with thick pods. If the type of *Pachypodium sagittatum* was collected it was evidently the typical form. Wyeth's route in 1833 has also been carefully followed in order to learn the exact location of the "Little Goddin River" with the result that this has been identified with the "Little Lost River" of southern Idaho. To any one familiar with the topography of this region it is easy to follow the references to familiar landmarks and so locate without doubt the places that were visited. The form of the species that occurs in southern Idaho is also that which is here considered typical. Consequently these two names which have been maintained with so much diffi-

culty and confusion for so many years seem to have been applied to plants of the same species.

8. T. stenopetalum Wats. Proc. Am. Acad. **22**: 468. 1887; Robinson in Gray, Syn. Fl. N. Am. **1**[1]: 176. 1895.

Probably biennial, glabrous and glaucous throughout: stem branched from the base, simple or sparingly branched above, slender, 3–6 dm. high: radical leaves soon withering, apparently oblanceolate, entire or repand; cauline leaves erect, sagittate at the base, narrowly lanceolate in outline, entire, acute, 3–5 cm. long: sepals purplish or green, linear, dorso-ventral pair slightly longer, hooded at the apex, about 1 cm. long; petals narrowly linear, somewhat crisped above, white or roseate, at least one-half longer than the sepals; filaments tetradynamous, linear, 8–14 mm. long; anthers coiled when dry, conspicuously apiculate, about 5 mm. long: inflorescence elongated, lax, racemose even before anthesis; pedicels ascending, 4–6 mm. long: pods slender, ascending, 4–5.5 cm. long, sessile; style not more than 1 mm. long, stigma very slightly 2-lobed.

Distribution: San Bernardino Mountains, southern California. Type: *Parish* "in Bear Valley, San Bernardino Mountains, on stony hillsides near the upper lake."

Specimens examined:

California: stony hillside, Upper Lake, Bear Valley, altitude 6500 ft., June, 1886, *S. B. Parish 1794* (Gray Herb., TYPE); same locality, June 16–20, 1895, *Parish 3787* (Gray Herb. and Univ. Calif. Herb.).

This is a most distinct species by virtue of the extraordinary petals. The septum is characteristically that of other members of this genus and there seems no reason to question its inclusion within *Thelypodium*.

9. T. flexuosum Robinson in Gray, Syn. Fl. N. Am. **1**[1]: 175. 1895; Howell, Fl. Northwest Am. 58. 1897; Frye & Rigg, Northwest Fl. 179. 1912.

Perennial, glabrous throughout: caudex clothed with the papery remains of previous leaf bases; stems 3–5 dm. long, slender, branched, subdecumbent, frequently flexuous, nearly naked above: radical leaves 8–15 cm. long, numerous, entire, lanceolate, gradually narrowed to the slender petiole; cauline leaves distant, lance-linear, acuminate, auriculate at the base with linear, acute lobes, the uppermost similar, much reduced: petals pale purplish

or white, spatulate, about twice as long as the sepals; filaments linear, anthers 1–2 mm. long, sagittate, not apiculate: inflorescence lax, at first corymbose, at maturity racemose; pedicels slender, divergent-ascending, 5–8 mm. long: pods conspicuously reticulate, irregularly torulose, shortly stipitate or subsessile, 15–22 mm. long; style slender, about 1 mm. long, stigma small, nearly circular: seeds not winged.

Distribution: eastern Oregon to northwestern Nevada. Type: *Anderson* from near Carson City, Nevada.

Specimens examined:

Oregon: alkaline plains, Malheur Butte, May 12, 1896, *Leiberg 2039* (Mo. Bot. Gard. Herb.); alkaline meadows, Powder River, May 23, 1898, *Cusick 1884* (Mo. Bot. Gard. Herb.); south of Big Springs, July 5, 1894, *Leiberg 396* (Rky. Mt. Herb. and Mo. Bot. Gard. Herb.).

Nevada: Minden, June 10, 1920, *Bethel* (Rky. Mt. Herb.); west of Antelope Valley, May 11, 1859, *H. Engelmann 77* (Mo. Bot. Gard. Herb.); Empire City, June 19, 1882, *Jones 3771* (Clokey Herb.).

10. T. laciniatum (Hook.) Endl. in Walp. Rep. 1: 172. 1842; Wats. Bot. King's Exp. 26. 1871; Gray, Proc. Am. Acad. 8: 377. 1873; Torr. Bot. Wilkes' Exp. 17: 231. 1874; Brewer & Wats. Geol. Survey Calif. Bot. 1: 37. 1876; Robinson in Gray, Syn. Fl. N. Am. 1¹: 177. 1895, in part; Howell, Fl. Northwest Am. 58. 1897, in part; Piper & Beattie, Fl. Palouse Region, 82. 1901, in part; Piper, Contr. U. S. Nat. Herb. 11: 299. 1906, in part; Frye & Rigg, Northwest Fl. 180. 1912; Piper & Beattie, Fl. Southeastern Washington and Adj. Idaho, 117. 1914; Piper & Beattie, Fl. Northwest Coast, 173. 1915.

Macropodium laciniatum Hook. Bot. Misc. 1: 341, *t. 68*. 1830; Hook. Fl. Bor. Am. 1: 43. 1840; Dietr. Syn. Pl. 3: 695. 1843.

Pachypodium laciniatum Nutt. in Torr. & Gray, Fl. N. Am. 1: 96. 1838.

P. ciliatum Dietr. Syn. Pl. 3: 702. 1843.

Thelypodium neglectum Jones, Am. Nat. 17: 875. 1882, in part.

T. leptosepalum Rydb. Bull. Torr. Bot. Club 34: 433. 1907; Rydb. Fl. Rocky Mountains, 367. 1917.

Biennial, glabrous throughout, more or less glaucous: stems usually stout, in the larger plants hollow, irregularly branching upwards, 3 24 dm. high: radical leaves petioled, thick, deltoid-

lanceolate, 1–5 dm. long, irregularly and deeply lobed, lobes acute or obtuse; cauline leaves petioled, the upper deeply pinnatifid to subentire: sepals similar, pale, acute, 4–7 mm. long; petals white, nearly linear, 7–21 mm. long, about 1 mm. broad; filaments slightly broadened at the base, 5–15 mm. long, anthers apiculate, 2–4 mm. long: inflorescence racemose, dense even when mature, 1–6 dm. long; pedicels stout, frequently flattened at the base, horizontal, 3–5 mm. long: pods widely spreading or recurved, 3–10 cm. long, about 1 mm. wide, somewhat flattened parallel to the septum; stipe 2–4 mm. long; style about 1 mm. long, stigma circular: seeds not winged.

Distribution: Idaho, northern Nevada, eastern Washington, and Oregon; northeastern California. Type: *Douglas* from near Walla Walla and at Priest's Rapid, Columbia River.

Specimens examined:

Idaho: Shoshone Falls, May 27, 1899, *Trelease 3991* (Mo. Bot. Gard. Herb.); Twin Falls and Shoshone Falls, July 25, 1911, *Nelson & Macbride 1343* (Mo. Bot. Gard. Herb. and Rky. Mt. Herb.); Shoshone Falls, June 11, 1912, *Bennitt 156* (Rky. Mt. Herb.); Twin Falls, May 13, 1912, *Bennitt 39* (Rky. Mt. Herb.); about Lewiston, May 6, 1896, *Heller & Heller 3022* (Univ. Calif. Herb. and Mo. Bot. Gard. Herb.).

Nevada: Palisade, June 14, 1882, *Jones 3767* (Mo. Bot. Gard. Herb., Rky. Mt. Herb., and Clokey Herb.); Pyramid Lake, Washoe County, May 19, 1905, *Kennedy 1003* (Rky. Mt. Herb.); Pyramid Lake, June 1, 1913, *Kennedy 1975* (Mo. Bot. Gard. Herb. and Rky. Mt. Herb.); Carson City, May 29, 1897, *Jones* (Rky. Mt. Herb.).

Washington: Yakima Region, 1882, *Brandegee 377* (Univ. Calif. Herb.); Ritzville, June 8, 1893, *Sandberg & Leiberg 190* (Mo. Bot. Gard. Herb.); Klickitat, 1879, *J. Howell* (Mo. Bot. Gard. Herb.); dry cliffs near Columbia River, Klickitat County, May 5–June, 1886, *Suksdorf 841* (Mo. Bot. Gard. Herb. and Univ. Calif. Herb.).

Oregon: 1871, *E. Hall 34* (Mo. Bot. Gard. Herb.); Barnhart, May 30, 1886, *Henderson 73* (Univ. Calif. Herb. and Mo. Bot. Gard. Herb.); Ione, Morrow County, July 13, 1903, *Lunell* (Rky. Mt. Herb.); Pine Creek, Gilliam County, June 7, 1894, *Leiberg* (Mo. Bot. Gard. Herb.); The Dalles, Aug., 1898, *Savage, Cameron & Lenocker* (Mo. Bot. Gard. Herb.).

California: near Yreka, Siskiyou County, May 23, 1876, *Greene 803* (Mo. Bot. Gard. Herb.); hills west of Big Pine, Inyo

County, May 15, 1906, *Heller 8262* (Univ. Calif. Herb. and Mo. Bot. Gard. Herb.); near Big Pine, May 30, 1906, *Hall & Chandler 7226* (Univ. Calif. Herb.).

A rather polymorphic species occurring in its typical form in eastern Washington and Oregon where it is characterized by slender, acute leaf segments. The type of *T. leptosepalum* accords very well with the drawing that accompanies the original description of *T. laciniatum* by Hooker.

10a. Var. **streptanthoides** (Leiberg) Payson, n. comb.

T. laciniatum Piper & Beattie, Fl. Palouse Region, 82. 1901, in part.

T. streptanthoides Leiberg, Contr. U. S. Nat. Herb. **11**: 299. 1906; Piper & Beattie, Fl. Southeastern Washington and Adj. Idaho, 117. 1914.

Leaves rather thin, deeply pinnatifid, lobes acute, narrow: sepals slightly saccate at the base, purple, at least on the upper third; petals white, linear: pedicels horizontal: pods recurved, glabrous, 6–12 cm. long.

Distribution: eastern Washington and Oregon. Type: *Sandberg & Leiberg 229* from "near Wilson Creek, Douglas County, Washington."

Specimens examined:

Washington: Almota, May 27, 1893, *Piper 1473* (Rky. Mt. Herb.); junction Crab and Wilson Creeks, Douglas County, June 19, 1893, *Sandberg & Leiberg 229* (Mo. Bot. Gard. Herb.).

Oregon: Riparia, May 31, 1905, *Jones* (Mo. Bot. Gard. Herb.); The Dalles, May 4, 1906, *Lunell* (Rky. Mt. Herb.).

Aside from the conspicuous color of the sepals little difference seems to exist between the variety and the typical form of the species. The leaves are said to be thinner and not at all glaucous. It is extremely doubtful, however, if this correlation will be found to be without exception, and further collections may show this plant deserving of formal rank only.

10b. Var. **milleflorum** (A. Nelson) Payson, n. comb.

T. laciniatum Robinson in Gray, Syn. Fl. N. Am. 1[1]: 177. 1895, in part; Howell, Fl. Northwest Am. 58. 1897, in part; Piper, Contr. U. S. Nat. Herb. **11**: 299. 1906, in part.

T. milleflorum A. Nelson, Bot. Gaz. **52**: 263. 1911; Frye & Rigg, Northwest Fl. 180. 1912; Rydb. Fl. Rocky Mountains, 367. 1917.

Glabrous and glaucous, stout: leaves thick, not so deeply lobed as in the species, the uppermost frequently nearly entire: sepals white, about 5 mm. long; petals linear-spatulate, 6–12 mm. long; filaments 7–10 mm. long, anthers apiculate: mature inflorescence dense, pedicels curved upwards, 3–4 mm. long: pods erect or strongly ascending, 2.5–6 cm. long, stipe 1–2 mm. long.

Distribution: Idaho, northern Nevada, eastern Washington, Oregon, and California. Type: *Macbride 234* from New Plymouth, Idaho.

Specimens examined:

Idaho: Shoshone, June 21, 1892, *Mulford* (Mo. Bot. Gard. Herb.); New Plymouth, June 10, 1910, *Macbride 234* (Mo. Bot. Gard. Herb. and Rky. Mt. Herb., TYPE); New Plymouth, May 2, 1911, *Macbride 796* (Rky. Mt. Herb. and Mo. Bot. Gard. Herb.); Pocatello, 1912, *Turesson 42* (Rky. Mt. Herb.); Arco, Blaine County, July 8, 1916, *Macbride & Payson 3094* (Rky. Mt. Herb. and Mo. Bot. Gard. Herb.); Idaho Falls, June 19, 1920, *Payson & Payson 1798* (Mo. Bot. Gard. Herb.).

Nevada: Simpson's Park, July 6, 1859, *H. Engelmann* (Mo. Bot. Gard. Herb.); Sprucemont, July 22, 1891, *Jones* (Univ. Calif. Herb.); Palisade, June 14, 1882, *Jones 3772* (Clokey Herb.); Reno, May, 1890, *Sonne* (Univ. Calif. Herb.); Carson City, May 29, 1897, *Jones* (Mo. Bot. Gard. Herb.); Eagle Valley, Ormsby County, June 7, 1902, *Baker 1020* (Mo. Bot. Gard. Herb. and Rky. Mt. Herb.).

Washington: Yakima County, 1883, *Brandegee 637* (Univ. Calif. Herb.); base of Rattlesnake Mountains, Yakima region, May 31, 1901, *Cotton 391* (Rky. Mt. Herb. and Mo. Bot. Gard. Herb.).

Oregon: dry bottoms, Malheur County, June 21, 1898, *Cusick 1955* (Mo. Bot. Gard. Herb., Rky. Mt. Herb., and Univ. Calif. Herb.).

California: Great Basin, Sierra Valley, July, 1875, *Lemmon 40* (Mo. Bot. Gard. Herb.).

With a limited series of specimens this variety seems quite distinct from the species because of the strongly ascending pods. With a more complete series, however, it is impossible to draw the dividing line definitely. In addition to this intergrading the distribution is very similar and it is therefore thought best to regard *milleflorum* as worthy of varietal distinction only.

11. T. rhomboideum Greene, Pittonia 4: 314. 1901.

T. integrifolium Robinson in Gray, Syn. Fl. N. Am. 1[1]: 176. 1895, in part.

Pleurophragma platypodum Rydb. Bull. Torr. Bot. Club 34: 434. 1907; Rydb. Fl. Rocky Mountains, 368. 1917.

Biennial, glabrous: stems erect, usually simple at the base and paniculately branched above, 4–14 dm. high: radical leaves oblanceolate, entire or sinuate-margined, 4–12 cm. long, usually obtuse; cauline leaves narrowly lanceolate to linear, reduced upwards, sessile or subsessile: sepals white or pale purple; petals white, narrowly spatulate, 6–8 mm. long; filaments 5–7 mm. long, anthers about 2 mm. long, not apiculate; nectar glands 4, horn-like processes: inflorescence very dense, scarcely corymbose; pedicels 3–5 mm. long, horizontal or somewhat reflexed, flattened conspicuously at the base: pods incurved, ascending, irregularly torulose, 2–3 cm. long; stipe 1–2 mm. long; style about 1 mm. long, stigma small, entire or slightly 2-lobed over the valves.

Distribution: western Colorado, Utah, and Nevada. Type: *Greene* from "the west Humboldt Mountains, Nevada."

Specimens examined:

Colorado: Hayden, Routt County, Aug. 6, 1903, *Goodding 1789* (Mo. Bot. Gard. Herb. and Rky. Mt. Herb.); Hot Sulphur Springs, Middle Park, Aug. 1, 1881, *G. Engelmann* (Mo. Bot. Gard. Herb.); Montrose or Ridgway, 1897, *Bethel* (Bethel Herb.).

Utah: Moab, Aug. 30, 1891, *Jones* (Univ. Calif. Herb., Rky. Mt. Herb., and Mo. Bot. Gard Herb.).

Arizona: near Tuba, Painted Desert, July 15–31, 1920, *Clute 82* (Mo. Bot. Gard. Herb.).

Nevada: spring in pass of Goshoot Mountains, July 20, 1859, *H. Engelmann 111* (Mo. Bot. Gard. Herb.); Wadsworth, Aug., 1876, *E. Palmer 22* (Univ. Calif. Herb. and Mo. Bot. Gard. Herb.); Reno, Aug. 13, 1889, *Hillman* (Univ. Calif. Herb.); Truckee Pass, Washoe County, Sept. 15, 1909, *Heller 9958* (Mo. Bot. Gard. Herb.).

It has been impossible to examine the type specimen of *T. rhomboideum*, since it can not be located at the Greene Herbarium at Notre Dame nor in other collections in which it might be expected. This uncertainty as to the identity of the type is complicated because the original description is far from complete. However, since only one species of this group is known

from the type locality of *T. rhomboideum* and since that species seems identical with the plant described as *T. platypodum*, the two are here united under the older name.

11a. Var. gracilipes (Robinson) Payson, n. comb.

T. integrifolium Endl. var. ? Brandegee in Hayden, Bull. Geol. & Geog. Survey of the Territories 2: 233. 1876.

T. integrifolium var. *gracilipes* Robinson in Gray, Syn. Fl. N. Am. 1¹: 176. 1895; Nelson in Coulter & Nelson, Manual Cent. Rocky Mountains, 209. 1909.

Thelypodium gracilipes Rydb. Fl. Colo. 167. 1906.

Pleurophragma gracilipes Rydb. Bull. Torr. Bot. Club 34: 433. 1907; Wooton & Standley, Contr. U. S. Nat. Herb. 19: 268. 1915; Rydb. Fl. Rocky Mountains, 368. 1917.

Sepals white or nearly so; petals white; nectar glands as in the species: stipe 2–3 mm. long.

Distribution: southwestern Colorado, northwestern New Mexico, and Utah. Type: *Brandegee 1233* from southwestern Colorado.

Specimens examined:

Colorado: Bedrock, Montrose County, Aug. 2, 1912, *Walker 369* (Rky. Mt. Herb.); banks of the San Juan River, Aug., 1875, *Brandegee 4278* (Mo. Bot. Gard. Herb.).

Utah: Armstrong and White Canyons, near the Natural Bridges, Aug. 4–6, 1911, *Rydberg & Garrett 9429* (Rky. Mt. Herb.).

12. T. integrifolium (Nutt.) Endl. Walp. Rep. 1: 172. 1842; Robinson in Gray, Syn. Fl. N. Am. 1¹: 176. 1895; Howell, Fl. Northwest Am. 58. 1897; Piper, Contr. U. S. Nat. Herb. 11: 299. 1906; Frye & Rigg, Northwest Fl. 180. 1912.

Pachypodium integrifolium Nutt. in Torr. & Gray, Fl. N. Am. 1: 96. 1838; Dietr. Syn. Pl. 3: 702. 1843.

Pleurophragma integrifolium Rydb. Bull. Torr. Bot. Club 34: 433. 1907, in part.

Biennial, glabrous throughout: stems erect, stout, branching, 6–15 dm. high: radical leaves oblong-elliptical, 1–3 dm. long, gradually narrowed to a broad petiole; cauline leaves linear-lanceolate, narrowed to a slender base, much reduced upwards and becoming linear in the inflorescence: petals spatulate, about 8 mm. long, exceeding the sepals by about one half, bluish or pale rose color; anthers about 2 mm. long, not apiculate; nectar glands

well developed into 2 pairs of horn-like processes: inflorescence at first corymbose, when mature somewhat elongated but remaining dense; pedicels 5–8 mm. long, slender and terete but usually somewhat wing-margined at the very base, horizontal or slightly ascending: pods irregularly torulose, arcuate, ascending, 2–3 cm. long, stipe 1–2 mm. long; styles less than 1 mm. long, stigmas small, entire: seeds frequently apiculate.

Distribution: Washington and Oregon. Type: *Nuttall* from "elevated plains of the Rocky Mountains towards the Oregon, as far as Wallawallah."

Specimens examined:

Washington: Satus, Yakima County, July, 1898, *Elmer 1073* (Mo. Bot. Gard. Herb.); Squaw Creek, Yakima County, Aug. 26, 1902, *Cotton 874* (Mo. Bot. Gard. Herb.); near Ellensburg, Sept., 1883, *Brandegee 636* (Univ. Calif. Herb.).

Oregon: valley of the Ochoco, July 23, 1901, *Cusick 2694* (Univ. Calif. Herb., Rky. Mt. Herb., and Mo. Bot. Gard. Herb.); near Prineville, Crook County, Aug. 26, 1894, *Leiberg 817* (Univ. Calif. Herb. and Mo. Bot. Gard. Herb.).

The identity of Nuttall's type of this species seems definitely established. The original description coincides more closely with the northwestern plant than with the nearly related species. Mr. J. F. Macbride who kindly examined a specimen at the Gray Herbarium that is evidently a co-type, writes me that the plant of Nuttall has pedicel bases that are definitely broadened and the pedicels themselves are about 6 mm. long. This broadening of the pedicel bases is characteristic of Washington material. The habitat as originally given would seem to indicate that the type locality was in the far northwest.

13. T. affine Greene, Pittonia 4: 314. 1901.

T. integrifolium Brewer & Wats. Geol. Survey Calif. Bot. 1: 37. 1876; Greene, Fl. Franciscana, 262. 1891; Robinson in Gray, Syn. Fl. N. Am. 1[1]: 176. 1895, in part.

Biennial, glabrous throughout, glaucescent: stem stout, paniculately branching above: radical leaves 10–25 cm. long, thick, oblanceolate, obtuse, irregularly margined or entire, blade narrowed to a broadly winged petiole: petals white (?), narrowly spatulate, 7–10 mm. long, much exceeding the sepals; stamens slightly exserted, anthers about 2 mm. long; nectar glands 2 (each pair coherent), well developed: inflorescence dense, scarcely corymbose; pedicels stout, nearly horizontal, 8–10 mm. long,

somewhat flattened at the base: pods horizontal-ascending, flattened laterally, 3–4.5 cm. long; stipe 1–2 mm. long; style stout, usually less than 1 mm. long, stigma small, entire.

Distribution: southern California. Type: *Greene,* from "mountains near Tehachapi."

Specimens examined:

California: Mojave Desert, Aug., 1881, *Parry* (Mo. Bot. Gard. Herb.); Mojave Desert, May, 1882, *Parish 1435* (Mo. Bot. Gard. Herb.); Victor, San Bernardino County, June 25–27, 1888, *E. Palmer 225* (Mo. Bot. Gard. Herb.); Rancho Verde, Victorville, San Bernardino County, June 25, 1915, *Parish 10532* (Univ. Calif. Herb.); Rabbit Springs, Mojave Desert, Aug., 1882, *S. B. & W. F. Parish 1485* (Univ. Calif. Herb.).

14. T. lilacinum Greene, Pl. Baker. **3**: 9. 1901.

Pachypodium integrifolium Hook. Hooker's London Jour. Bot. **6**: 70. 1847, not Nutt.

Thelypodium integrifolium Torr. & Gray, Pac. Rail. Rept. **2**: 126. 1855; Porter & Coulter, Syn. Fl. Colo. 9. 1874; Coulter, Manual Rocky Mountain Region, 21. 1885; Robinson in Gray, Syn. Fl. N. Am. 1^1: 176. 1895, in part; Nelson, First Rept. Fl. Wyo. 204. 1896; Britton & Brown, Ill. Fl. **2**: 110. 1897, and ed. 2, 2: 169. 1913; Britton, Manual, 444. 1901; Rydb. Fl. Colo. 167. 1906; Nelson in Coulter & Nelson, Manual Cent. Rocky Mountains, 209. 1909; Petersen, Fl. Nebraska, 60. 1912; Clements & Clements, Rocky Mountain Flowers, 28. 1914; Bergman, Flora North Dakota, 193. 1918.

Pleurophragma integrifolium Rydb. Bull. Torr. Bot. Club **34**: 433. 1907, in part; Wooton & Standley, Contr. U. S. Nat. Herb. **19**: 267. 1915; Rydb. Fl. Rocky Mountains, 368. 1917, in part.

Biennial, glabrous throughout: stems erect, branched from the base or simple, paniculately branched above, 3–24 dm. high: radical leaves entire, oblanceolate, 4–12 cm. long, obtuse; cauline leaves narrowly lanceolate to linear, reduced upwards, sessile by a narrow base or slightly auriculate: sepals purple to white; petals spatulate, 7–9 mm. long, purple, pale blue, lilac or nearly white; anthers 2–3 mm. long; nectar glands low and rounded: inflorescence at first corymbose, elongating when mature, frequently rather lax; pedicels horizontal or ascending, slender, 5–10 mm. long, not conspicuously flattened at the base: pods irregularly torulose, arcuate-ascending, 1.5–3.5 cm. long; stipe usually less than 1 mm. long; style about 1 mm. long, stigma entire.

Distribution: western Nebraska, southern Wyoming, Colorado, northwestern New Mexico, Utah, and southern Idaho. Type: *Baker 635* from Doyle's, Gunnison County, Colorado.

Specimens examined:

Nebraska: sandhills of the Platte, Aug., 1855, *Hayden* (Mo. Bot. Gard. Herb.); north fork of the Platte, toward Ft. Laramie, July, 1858, *H. Engelmann 110* (Mo. Bot. Gard. Herb.); south fork of the Platte, July, 1856, *H. Engelmann* (Mo. Bot. Gard. Herb.); Bridgeport, Cheyenne County, Aug. 6, 1901, *Baker* (Mo. Bot. Gard. Herb.).

Wyoming: Lusk, July 21, 1894, *Nelson 574* (Mo. Bot. Gard. Herb.); Laramie, Aug. 10, 1895, *Nelson 1663* (Rky. Mt. Herb.); open, saline soils, Albany County, July 16, 1900, *Nelson 7606* (Rky. Mt. Herb. and Mo. Bot. Gard. Herb.); Jones' Ranch, Albany County, July 24, 1903, *Nelson* (Rky. Mt. Herb.); Laramie, July 28, 1913, *Macbride 2569* (Mo. Bot. Gard. Herb.); Laramie, Sept. 20, 1913, *Sharp 432* (Rky. Mt. Herb.); Wind River, near Dubois, Aug. 9, 1894, *Nelson 747* (Rky. Mt. Herb.); Granger, Hams Fork, July 30, 1897, *Nelson 4140* (Rky. Mt. Herb.); near Ft. Bridger, Aug., 1872, *Leidy* (Mo. Bot. Gard. Herb.).

Colorado: lat. 40–41°, *Vasey* (Mo. Bot. Gard. Herb.); lat. 41°, 1862, *Hall & Harbour 51* (Mo. Bot. Gard. Herb.); 1909, *Johnston 598* (Rky. Mt. Herb.); New Windsor, July 22, 1901, *Osterhout* (Rky. Mt. Herb.); Fort Collins, Aug. 8, 1895, *Crandall* (Mo. Bot. Gard. Herb.); banks of the Cache le Poudre River near Fort Collins, Aug. 9, 1898, *Crandall* (Rky. Mt. Herb.); Wet Mountain Valley, Aug., 1873, *Brandegee 821* (Univ. Calif. Herb. and Mo. Bot. Gard. Herb.); Hot Sulphur Springs, Aug. 1, 1881, *G. Engelmann* (Mo. Bot. Gard. Herb.); near Hot Sulphur Springs, Aug. 3–8, 1907, *Ramaley & Robbins 3627* (Rky. Mt. Herb.); Parlins, June, 1888, *Eastwood* (Bethel Herb.); Doyle's, July 29, 1901, *Baker 365* (Mo. Bot. Gard. Herb.).

Idaho: near Clayton, Custer County, July 22, 1916, *Macbride & Payson 3360* (Mo. Bot. Gard. Herb. and Rky. Mt. Herb.); Blackfoot, Aug. 9, 1892, *Mulford* (Mo. Bot. Gard. Herb.); Twin Falls and Shoshone Falls, July 26, 1911, *Nelson & Macbride 1349* (Rky. Mt. Herb. and Mo. Bot. Gard. Herb.).

Utah: Logan, Aug. 12, 1909, *Smith 2003* (Rky. Mt. Herb.); near Midway, Wasatch County, July 6, 1905, *Carlton & Garrett 6705* (Rky. Mt. Herb.); Ephraim, June 27, 1894, *Jones 5522* (Mo.

Bot. Gard. Herb.); along the Sevier River, above Marysvale, July 19, 1905, *Rydberg & Carlton 6926* (Rky. Mt. Herb.).

The group of specimens here cited is more or less polymorphic but it is believed that further taxonomic segregation would be of no advantage. Color differences are difficult of detection in the herbarium, and there is every reason to believe that the colors are quite variable in the field although some geographic localization of color forms certainly occurs. In Colorado, for example, the form on the eastern slope of the Continental Divide is mostly white-flowered and on the western slope mostly purple. This purple form of western Colorado is the typical *lilacinum* of Greene. In Utah white-flowered plants seem to predominate, while in southern Idaho the purple-flowered form again appears.

14a. Var. subumbellatum Payson, n. var.[1]

Thelypodium integrifolium Robinson in Gray, Syn. Fl. N. Am. 1[1]: 176. 1895, in part; Rydb. Mem. N. Y. Bot. Gard. 1: 172. 1900; Nelson in Coulter & Nelson, Manual Cent. Rocky Mountains, 209. 1909, in part.

Pleurophragma integrifolium Rydb. Fl. Rocky Mountains, 368. 1917, in part.

Radical leaves oblanceolate, 8–15 cm. long, 1.5–2.5 cm. broad, narrowed to a broad petiole: nectar glands low and rounded: mature inflorescence congested, subumbellate, 2–3 cm. long; pedicels slender, terete: stipes 0.5–1 mm. long.

Distribution: southwestern Montana, western Wyoming, southern Idaho, Utah.

Specimens examined:

Montana: Prickly Pear, July 15, 1898, *E. N. B.* (Univ. Calif. Herb.); Helena, 1887, *Kelsey 257* (Univ. Calif. Herb.); Deep Creek near Anaconda, Aug. 24, 1905, *Jones* (Mo. Bot. Gard. Herb.); alkali flats, Three Forks, Aug. 10, 1899, *Blankinship* (Mo. Bot. Gard. Herb.).

Wyoming: near Mammoth Hot Springs, Yellowstone Nat. Park, Aug., 1893, *Burglehaus* (Mo. Bot. Gard. Herb., TYPE, and Rky. Mt. Herb.); Mammoth Hot Springs, July 2, 1899, *Nelson & Nelson 6034* (Rky. Mt. Herb. and Mo. Bot. Gard. Herb.); Mammoth Hot Springs, July 8, 1900, *Jones* (Univ. Calif. Herb.);

[1]**Thelypodium lilacinum** Greene, **var. subumbellatum** var. nov., **biennе glabrum**; foliis radicalibus oblanceolatis 8–15 cm. longis 1.5–2.5 cm. latis; **racemis fructiferis densis subumbellatis**; pedicellis gracilibus teretibus.—Collected by ***F. H. Burglehaus*** **near Mammoth Hot Springs, Yellowstone National Park, Wyoming, Aug., 1893. (Mo. Bot. Gard. Herb., TYPE).**

Yellowstone Nat. Park, July, 1904, *Oleson 242* (Rky. Mt. Herb.).

Idaho: saline flats, American Falls, July 28, 1911, *Nelson & Macbride 1380* (Mo. Bot. Gard. Herb. and Rky. Mt. Herb.).

Utah: 1847, *Parry* (Mo. Bot. Gard. Herb.).

CHLOROCRAMBE

CHLOROCRAMBE Rydb. Bull. Torr. Bot. Club **34**: 435 1907.

Perennial herb with rather stout, erect stem and thin, petioled, more or less hastate leaves. Flowers greenish yellow in a loose, virgate raceme, slightly deflexed; sepals similar, spreading; petals dentate or laciniately toothed laterally. Pods widely spreading, subterete, shortly stipitate; stigma entire; cells of septum elongated parallel to the replum, not tortuous. Seeds neither winged nor margined; cotyledons obliquely accumbent. Generic type: *C. hastata* (Wats.) Rydb.

1. C. hastata (Wats.) Rydb. Bull. Torr. Bot. Club **34**: 435. 1907; Rydb. Fl. Rocky Mountains, 365. 1917.

Caulanthus hastatus Wats. Bot. King's Exp. 28. *t. 3.* 1871; Robinson in Gray, Syn. Fl. N. Am. 1[1]: 173. 1895; Howell, Fl. Northwest Am. 47. 1897; Nelson in Coulter & Nelson, Manual Cent. Rocky Mountains, 210. 1909; Garrett, Spring Flora of the Wasatch Region, 48. 1912.

Perennial, glabrous throughout: stem erect, simple or sparingly branched, rather stout, 6–15 dm. high: all except the uppermost leaves ample; blade broadly deltoid, hastate or lanceolate, entire or coarsely and irregularly lobed, 5–10 cm. long, base usually truncate, at times subcordate; petioles of lower leaves 8–15 cm. long, becoming shorter above, frequently appendaged with several entire or irregularly lobed segments of the blade; uppermost leaves narrowly lanceolate, entire, much reduced: sepals greenish white, nearly equal, not saccate at the base, narrowly lanceolate, about 6 mm. long, slightly spreading, distant; petals whitish, somewhat exceeding the sepals, irregularly dentate or sublaciniate laterally towards the base, narrower and frequently linear above; filaments linear, slightly enlarged near the base, distinctly longer than the petals, anthers 3–4 mm. long, apiculate; nectar glands rather well developed: inflorescence racemose; pedicels deflexed-divaricate, enlarged at the apex, somewhat laterally compressed at the base, 7–10 mm. long: pods widely spreading, subterete, slightly flattened parallel

to the septum, 4–7 cm. long; stipe 1–7 mm. long; style very short, stigma capitate, entire: cotyledons in seed obliquely accumbent.

Distribution: from central Utah to southeastern Oregon. Type: *Watson 114* from "shaded slopes in the Wahsatch and Uinta Mountains," Utah.

Specimens examined:

Utah: American Fork Canyon, July 31, 1880, *Jones 1358* (Mo. Bot. Gard. Herb.).

Oregon: Wallowa Mountains, near the lake, July 31, 1899, *Cusick 2292* (Univ. Calif. Herb. and Mo. Bot. Gard. Herb.).

CAULANTHUS

CAULANTHUS Wats. Bot. King's Exp. 27. 1871; Brewer & Wats. Geol. Survey Calif. Bot. 1: 36. 1876; Robinson in Gray, Syn. Fl. N. Am. 1[1]: 172. 1895; Rydb. Fl. Rocky Mountains, 364. 1917.

Streptanthus Gray, Proc. Am. Acad. 6: 182. 1866, in part; Greene, Fl. Franciscana, 256. 1891, in part.

Stanfordia Wats. in Brewer & Wats. Geol. Survey Calif. Bot. 2: 479. 1880.

Thelypodium Greene, Fl. Franciscana, 262. 1891, in part; Robinson in Gray, Syn. Fl. N. Am. 1[1]: 173. 1895, in part; Jepson, Fl. West. Mid. Calif. 212. 1901, and ed. 2, 180. 1911; Rydb. Fl. Rocky Mountains, 366. 1917, in part.

Guillenia Greene, Leafl. Bot. Obs. & Crit. 1: 227. 1906, in part.

Mostly annual herbs, frequently glabrous and glaucous or in some species pubescent with simple trichomes. Stems branched or unbranched, slender, stout or conspicuously inflated. Except in a few species the radical leaves do not form a conspicuous rosette and are not sharply differentiated from the cauline leaves. Cauline leaves amplexicaul, sessile or petioled. Flowers purple, white or yellow; calyx segments equal or quite unequal; petals frequently narrow and crisped, blade usually not differentiated from the claw. Inflorescence usually racemose. Pods divaricate, erect or deflexed, usually glabrous, terete (if flattened not over 3 mm. wide), sessile or nearly so; style usually short, stigma entire or 2-lobed with the lobes extended over the center of the valves; cells of the septum usually short and the boundaries straight. Seeds wingless or narrowly winged; cotyledons usually obliquely incumbent. Generic type: *C. crassicaulis* (Torr.) Wats.

Key to the Species

A. Cauline leaves sessile and auriculate at the base.
  a. Glabrous or inconspicuously short-pubescent.
    I. Stems not conspicuously inflated.
      *Stigma entire or shallowly 2-lobed; cotyledons entire.
        1. Pods erect or divaricate.
          0. Pods 6–8 cm. long; flowers purplish ---------- *1. C. amplexicaulis*
          00. Pods about 1.5 cm. long; flowers yellow ---------- *2. C. sulfureus*
        2. Pods reflexed ---------- *9. C. Cooperi*
      **Stigma deeply 2-lobed; cotyledons trifid *14. C. californicus*
    II. Stems conspicuously inflated; stigma deeply 2-lobed; pods erect or divaricate ---- *3. C. inflatus*
  b. More or less hirsute or pilose.
    I. Seeds not winged or margined; pods nearly or quite terete.
      *Stigma distinctly 2-lobed.
        1. Pods 4–14 cm. long; cotyledons entire.
          0. Pods usually reflexed.
            x. Stigma shallowly 2-lobed; calyx yellowish ---------- *10. C. simulans*
            y. Stigma deeply 2-lobed; calyx purple ---------- *11. C. Coulteri*
          00. Pods erect, 8–13 cm. long ---- *12. C. Lemmonii*
        2. Pods 2–4 cm. long; cotyledons trifid *14. C. californicus*
      **Stigma very small, nearly entire ------ *15. C. stenocarpus*
    II. Seeds narrowly winged; pods compressed or quadrangular, reflexed ---------- *13. C. heterophyllus*
B. Cauline leaves sessile or petioled, not auriculate.
  a. Stem conspicuously inflated.
    I. Calyx glabrous.
      *Mature stigma shallowly 2-lobed ------ *7. C. major*
      **Mature stigma deeply 2-lobed ---------- *8a. C. crassicaulis* var. *glaber*
    II. Calyx densely hispid.
      *Annual; leaves more or less hispid ----- *6. C. Hallii*
      **Short-lived perennial; leaves glabrous --- *8. C. crassicaulis*
  b. Stem not inflated.
    I. Calyx densely hispid.
      *Annual; leaves hispid ---------- *6. C. Hallii*
      **Short-lived perennial; leaves glabrous --- *8. C. crassicaulis*
    II. Calyx glabrous or sparsely pilose.
      *Pods erect or divaricate.
        1. Style short, enlarged to a conspicuous stigma, not conic.
          0. Plant glabrous.
            x. Tuft of radical leaves not persisting; annual ------ *4. C. glaucus*
            y. Tuft of radical leaves persisting; short-lived perennial ---------- *7. C. major*
          00. Plant densely pilose --- ----- *5. C. pilosus*
        2. Style 2–4 mm. long, conic; stigma minute.
          0. Flowers large, yellow; petals crisped, 9–15 mm. long ------ *16. C. flavescens*
          00. Flowers not over 5 mm. long; petals flat.
            x. Sepals purplish, spreading. *17. C. anceps*

y. Sepals green or yellow, erect.
†Pods slender on slender pedicels ----------*18a. C. lasiophyllus* var. *inalienus*
††Pods stout on very stout pedicels ------*18b. C. lasiophyllus* var. *rigidus*

**Pods reflexed.
1. Lobes of the leaves usually acute; plants of the coastal region------*18. C. lasiophyllus*
2. Lobes of the leaves usually rounded, leaves thinner, more nearly glabrous; plants of the interior------*18c. C. lasiophyllus* var. *utahensis*

1. C. amplexicaulis Wats. Proc. Am. Acad. 17: 364. 1882; Robinson in Gray, Syn. Fl. N. Am. 1[1]: 172. 1895.

Euclisia amplexicaulis Greene, Leafl. Bot. Obs. & Crit. 1: 84. 1904.

Annual, glabrous throughout, more or less glaucous: stem slender, somewhat decumbent at the base, simple or branched, flexuous, 2–4 dm. long: stem-leaves from suborbicular to ovate or oblong, obtuse, 2–5 cm. long, deeply amplexicaul at the base, basal lobes rounded, leaf margin entire or in the lower leaves sinuate-dentate: sepals purplish, somewhat saccate above the base, particularly the dorso-ventral pair, nearly equal in length, about 7 mm. long; petals purplish, broadly linear, about 11 mm. long, upper part strongly crisped and becoming coiled; filaments linear, tetradynamous, 4–7 mm. long, anthers about 5 mm. long, scarcely apiculate: inflorescence lax, racemose; pedicels ascending or divaricate, 12–20 mm. long: pods spreading, curved, terete, slender, 6–8 cm. long; stipe stout, less than 1 mm. long; style not over 1 mm. long, stigma small, entire; cells of septum rectangular, short, not at all tortuous.

Distribution: southern California. Type: *S. B. & W. F. Parish* from the San Bernardino Mountains.

Specimens examined:

California: San Bernardino Mountains, *W. G. Wright* (Univ. Calif. Herb.); San Bernardino Mountains, April, 1881, *S. B. & W. F. Parish 846* (Mo. Bot. Gard. Herb.); head of Waterman's Canyon, June 6, 1892, *Parish 2326* (Univ. Calif. Herb.); head of Waterman's Canyon, San Bernardino Mountains, June, 1894, *Parish* (Univ. Calif. Herb.); Grass Valley, San Bernardino Mountains, June 28, 1894, *Parish 3036* (Mo. Bot. Gard. Herb.); Mill Creek, at the falls, San Bernardino Mountains, May 30, 1898, *Hall 918* (Univ. Calif. Herb. and Mo. Bot. Gard. Herb.); Manzana, Antelope Valley, May 9–24, 1896, *Davy 2563* (Univ. Calif. Herb.);

near Manzana, Antelope Valley, May 9–24, 1896, *Davy 2469* (Univ. Calif. Herb.); Lytle Creek Canyon, San Antonio Mountains, June 1–3, 1900, *Hall 1436* (Univ. Calif. Herb.); Mt. San Antonio, San Bernardino County, July 12, 1902, *Abrams 2699* (Mo. Bot. Gard. Herb.); San Francisquito Pass, May 3, 1902, *Hall 3101* (Univ. Calif. Herb.).

Because of the entire stigma this plant is somewhat anomalous in *Caulanthus* and approaches the *Sisymbrioid* genera. The floral characters are, however, those of *Caulanthus* and in this group it seems to find its nearest allies.

So closely related to this species is *Streptanthus campestris* Wats. that in an immature condition the two are likely to be confused. That species seems to be biennial rather than annual, is a stouter plant than *C. amplexicaulis*, has winged seeds and a septum with tortuous cell walls. The sepals in the *Caulanthus* species are glabrous, while in *S. campestris* they are sparingly hirsute at the apex. *S. campestris* might, without offense to phylogeny, be united with *Caulanthus* except that there is perhaps a more definite line of cleavage between this species and *Caulanthus* than between it and other *Streptanthus* species. Accordingly, unless *Streptanthus* be merged with *Caulanthus*, here is the logical point of division.

2. C. sulfureus Payson, n. sp.[1]

Root and lower part of the stem unknown, glabrous and glaucous above: stem branched in the inflorescence, rather stout: upper cauline leaves ovate, acuminate, amplexicaul at the base with rounded lobes, 3–5 cm. long: sepals yellowish, nearly equal, about 5 mm. long, lateral pair slightly saccate at the base; petals yellow, oblanceolate, 1–1.5 times as long as the sepals, scarcely clawed, margin slightly sinuate-dentate; filaments distinct, strongly tetradynamous, linear, 3–5 mm. long, anthers shortly apiculate, 2–3 mm. long; nectar glands 4, well developed: inflorescence corymbose or shortly racemose at first, elongating when mature; pedicels slender, ascending, 10–13 mm. long: pods

[1]**Caulanthus sulfureus** sp. nov., glabrus glaucus; radice et caule inferno ignoto, caule superno ramoso robusto; foliis caulinis integris ovatis acuminatis 3–5 cm. longis amplexicaulibus, lobis basi rotundis; sepalis subflavis circiter 5 mm. longis, lateralibus subsaccatis, petalis flavis oblanceolatis 5–8 mm. longis, filamentis tetradynamis 3–5 mm. longis distinctis; inflorescentiis primo corymbosis, serius racemosis, pedicellis gracilibus patentibus 10–13 mm. longis; siliquis (immaturis) erectis subsessilibus circiter 1.5 cm. longis, stylo 1.5 mm. longo, stigmate subbilobo.—Collected on Santa Cruz bottoms near Tucson, Arizona, March 13–April 23, 1903, *David Griffiths 4058* (Mo. Bot. Gard. Herb., TYPE).

(immature) erect or ascending, terete, subsessile, about 1.5 cm. long; style rather stout, 1.5 mm. long, stigma capitate, in age 2-lobed; cells of septum short, rectangular, not at all tortuous.

Distribution: southern Arizona.

Specimen examined:

Arizona: Santa Cruz bottoms near Tucson, March 13–April 23, 1903, *David Griffiths 4058* (Mo. Bot. Gard. Herb., TYPE).

The generic affinities of this plant are not quite clear. The position of the stigmatic lobes, which are definitely over the valves, excludes the possibility of allying it with those species recently segregated as *Thelypodiopsis*, and to which the plant bears considerable habital resemblance. *Thelypodium* is also, for the present, excluded for several reasons. The septum is unlike that of any species of *Thelypodium* known, but it is similar to the typical septum of *Caulanthus*. The rather large stigma that becomes bilobed suggests the latter genus also. Yellow is a color not yet admitted to *Thelypodium* but is of common occurrence in *Caulanthus*. The range also would point to the probability that this plant was derived from *Caulanthus* rather than from the northwestern genus.

3. C. inflatus Wats. Proc. Am. Acad. **17**: 364. 1882; Coville, Contr. U. S. Nat. Herb. 4: 62. 1893; Robinson in Gray, Syn. Fl. N. Am. 1[1]: 172. 1895.

Streptanthus inflatus Greene, Fl. Franciscana, 257. 1891.

Annual, glabrous or sparingly hirsute near the base, sometimes glaucous: stem erect, usually unbranched, stout, becoming conspicuously inflated above the middle, hollow, 3–6 dm. high: all the leaves with auriculate or clasping bases, the lowermost narrowed above the basal lobes; cauline leaves ovate to oblong, mostly acute, entire, 3–7 cm. long: sepals purple in the bud, in anthesis white with purple tips, glabrous, nearly equal in length, dorso-ventral pair slightly saccate at the base, scarious-margined, acute, 8–10 mm. long; petals white, broadly linear, crisped near the apex, but little longer than the sepals; filaments stout, longer pairs coherent for more than half their lengths, shorter than or equalling the calyx; anthers broadly apiculate, about 3 mm. long: inflorescence racemose; pedicels stout, more or less villous, ascending, about 3 mm. long: pods rather stout, 6–10 cm. long, erect or ascending, subsessile; style very short or obsolete, stigma deeply 2-lobed: cotyledons obliquely accumbent, seed-coat mucilaginous when boiled.

Distribution: southern California. Type: *Lemmon* from the Mojave Desert.

Specimens examined:

California: Mojave Desert, *Davidson* (Univ. Calif. Herb.); Mojave Desert, May 25, 1882, *Pringle* (Mo. Bot. Gard. Herb.); Fremont's Peak, Mojave Desert, May 6, 1906, *Hall & Chandler 6862* (Univ. Calif. Herb.); Sunset, Kern County, April 20, 1902, *Heller 7724* (Univ. Calif. Herb. and Mo. Bot. Gard. Herb.); Randsburg, Kern County, April 14, 1905, *Heller 7702* (Univ. Calif. Herb. and Mo. Bot. Gard. Herb.); Mojave Station, March 15, 1889, *Hasse* (Mo. Bot. Gard. Herb.); Antelope Valley, 1895, *Davidson* (Univ. Calif. Herb.); near Rosamond, Antelope Valley, May 9–24, 1896, *Davy 2272* (Univ. Calif. Herb.); Lancaster, June, *Davidson* (Univ. Calif. Herb.); Bakersfield, April 4, 1893, *Eastwood* (Univ. Calif. Herb.); Zapato Chino Creek, March 25–26, 1893, *Brandegee* (Univ. Calif. Herb.).

4. C. glaucus Wats. Proc. Am. Acad. 17: 364. 1882; Robinson in Gray, Syn. Fl. N. Am. 1[1]: 173. 1895.

Duration of root unknown, plant glabrous and glaucous throughout: stem erect, simple or sparingly branched, frequently flexuous below, rather stout, 3–8 dm. high: radical leaves not certainly known; lowermost stem-leaves rather thick, entire or repand, blade ovate or broadly elliptical, obtuse, 3.5–7 cm. long, abruptly narrowed to a petiole 2–4 cm. long; upper stem-leaves reduced, narrowly lanceolate: sepals greenish or purplish, narrow, not saccate at the base, nearly equal, 8–10 mm. long, with a very narrow scarious margin; petals greenish, broadly linear, recurved at the apex, about 1.5 cm. long; filaments linear, slender, nearly equal, 5–7 mm. long, anthers barely apiculate, 4–5 mm. long: inflorescence racemose; pedicels slender, 7–15 mm. long, enlarged at the apex: pods widely divaricate, frequently arcuate, 6–8 cm. long, rather slender, subsessile; style nearly obsolete, stigma enlarged, deeply 2-lobed: cotyledons obliquely accumbent in the seed.

Distribution: southwestern Nevada and adjacent California. Type: *Shockley* from Candelaria, Esmeralda County, Nevada.

Specimens examined:

Nevada: Tonopah, April 24, 1907, *Jones* (Mo. Bot. Gard. Herb.); Gold Mountain, May–Oct., 1898, *Purpus 5974* (Univ. Calif. Herb.); Candelaria, Esmeralda County, May, *Shockley 19*

(Univ. Calif. Herb. and Mo. Bot. Gard. Herb.); Candelaria, June 22, 1882, *Jones 3775* (Mo. Bot. Gard. Herb.).

California: Bishop, Owen's Valley, May 15, 1897, *Jones* (Mo. Bot. Gard. Herb.); Silver Canyon, White Mountains, Inyo County, May 7, 1906, *Heller 8193* (Mo. Bot. Gard. Herb.).

5. C. pilosus Wats. Bot. King's Exp. 27. 1871; Brewer & Wats. Geol. Survey Calif. Bot. 1: 36. 1876; Coville, Contr. U. S. Nat. Herb. 4: 62. 1893; Robinson in Gray, Syn. Fl. N. Am. 1[1]: 173. 1895; Howell, Fl. Northwest Am. 48. 1897.

Biennial or short-lived perennial, sparingly pilose to densely hirsute, especially near the base: radical- and lower stem-leaves similar, petioled, oblanceolate in outline, coarsely toothed or pinnatifid, acute or obtuse, 4–15 cm. long; upper cauline leaves reduced, sparingly pinnatifid to entire, narrowed to a slender base: sepals green or purplish, more or less densely pilose, scarious margined, 5–8 mm. long; petals apparently white or veined with purple, narrowly spatulate, crisped apex curved outwards, 7–10 mm. long; filaments slightly broader at the base, distinct, about as long as the sepals, anthers somewhat apiculate, about 5 mm. long; inflorescence racemose; pedicels ascending, 5–8 mm. long: pods ascending or widely divaricate, frequently arcuate, 6–13 cm. long, about 1.5 mm. in diameter, subsessile; style short, stigma conspicuously 2-lobed: position of cotyledons and radicle in the seed very variable, from completely incumbent to obliquely accumbent.

Distribution: southwestern Idaho, western Nevada, eastern Oregon, and eastern California. Type: *Watson 113* from the Truckee Valley, Nevada.

Specimens examined:

Idaho: Weiser, April 18, 1900, *Jones 6170* (Mo. Bot. Gard. Herb.); New Plymouth, May 21, 1910, *Macbride 88* (Mo. Bot. Gard. Herb.); Emmett, Canyon County, June 9, 1911, *Macbride 883* (Mo. Bot. Gard. Herb. and Univ. Calif. Herb.).

Nevada: Simpson's Valley, May 26, 1859, *H. Engelmann* (Mo. Bot. Gard. Herb.); Candelaria, *Shockley 5* (Univ. Calif. Herb.); Candelaria, June 22, 1882, *Jones 3777* (Mo. Bot. Gard. Herb.); Gold Mountain, May–Oct., 1898, *Purpus 5956* (Univ. Calif. Herb.).

Oregon: stony hillsides of Powder River near the mouth, June 3, 1901, *Cusick 2541* (Mo. Bot. Gard. Herb. and Univ. Calif. Herb.); hills near Malheur River, Malheur County, June 7,

1901, *Cusick 2546* (Mo. Bot. Gard. Herb. and Univ. Calif. Herb.).

California: Darwin, April 28, 1897, *Jones* (Mo. Bot. Gard. Herb. and Univ. Calif. Herb.); Darwin Valley, Inyo County, May 19, 1906, *Hall & Chandler 7100* (Univ. Calif. Herb.); south of Bishop, Inyo County, May 21, 1906, *Heller 8295* (Mo. Bot. Gard. Herb. and Univ. Calif. Herb.); Lone Pine Creek, Inyo County, May 27, 1906, *Hall & Chandler 7206* (Univ. Calif. Herb.).

6. C. Hallii Payson, n. sp.[1]

Annual, sparingly hispid-hirsute on the leaves and pedicels: stem glabrous, somewhat glaucous, simple or paniculately branched above, hollow, with a tendency to become inflated, erect, 5–8 dm. high: cauline leaves 4–16 cm. long, irregularly and deeply laciniate-pinnatifid or dentate with few, coarse lobes: sepals apparently yellowish, hispid-hirsute, lanceolate, nearly similar and equal, not saccate, about 6 mm. long; petals probably yellow, narrowly spatulate, about 9 mm. long; filaments in three pairs as to length, distinct, linear, 4, 5, and 6 mm. long, anthers not apiculate, about 3 mm. long; nectar glands rather well developed: inflorescence lax, racemose; pedicels widely divergent, 6–18 mm. long: pods terete, subsessile, divaricate, glabrous, 7–11 cm. long, 1.5 mm. wide; style nearly obsolete to 2 mm. long, stigma deeply 2-lobed: cells of septum rectangular, short.

Distribution: San Jacinto Mountains, southern California.

Specimens examined:

California: Coyote Canyon at 5000 ft. alt., on El Toro Mountain, May 25, 1899, *H. M. Hall 1165* (Mo. Bot. Gard. Herb., TYPE); Coyote Canyon, Santa Rosa Mountain, May 17–June 1, 1901, *Hall 1902* (Univ. Calif. Herb.).

This species seems to be as distinct as any unit that has been proposed in this genus and should not be confused with any other species. The tendency to inflation of the stem is suggestive of *C. major* or *C. crassicaulis*. The specific description was drawn from a single and somewhat fragmentary specimen, and the measurements may be found not sufficiently inclusive for other

[1] **Caulanthus Hallii** sp. nov., annuus; caule glabro glauco superne ramoso fistuloso, subinflato erecto 5–8 dm. alto; foliis caulinis 4–6 cm. longis hispidulis non amplexicaulibus laciniato-pinnatifidis, lobis disparibus paucis; sepalis subflavis similibus hispidis, petalis flavis spatulatis 9 mm. longis, filamentis distinctis 4, 5, et 6 mm. longis; inflorescentiis primo racemosis laxis, pedicellis patentibus 6–18 mm. longis; siliquis teretibus subsessilibus patulis glabris 7–11 cm. longis 1.5 mm. latis, stylo brevissimo, stigmate bilobo.—Collected in Coyote Canyon, on El Toro Mountain, California, May 25, 1899, by *H. M. Hall 1165* (Mo. Bot. Gard. Herb., TYPE).

representatives of this species. This plant is dedicated to the collector, my friend, *Dr. H. M. Hall.* It is perhaps most closely related to *C. pilosus* Wats.

7. C. major (Jones) Payson, n. comb.

C. crassicaulis (Torr.) Wats. var. *major* Jones, Proc. Calif. Acad. III, 5: 623. 1895.

C. procerus Rydb. Fl. Rocky Mountains, 364. 1917, not Wats.

Short-lived perennial, glabrous and glaucous throughout: stems erect, simple or sparingly branched, hollow, not at all, or rarely somewhat inflated, frequently several from the root, 4–9 dm. high: radical- and lower stem-leaves oblanceolate in outline, entire, lyrate or runcinate, 5–15 cm. long, narrowed to a slender petiole; upper stem-leaves linear to lanceolate, few, much reduced: sepals purple or yellowish tipped with purple, not saccate, nearly equal, 7–10 mm. long; petals purplish, broadly linear or with slightly dilated, crisped blade, 1.5–2 times as long as the sepals; filaments equalling or shorter than the sepals, anthers broadly apiculate, 3–4 mm. long: inflorescence racemose; pedicels very stout, ascending, 3–5 mm. long: pods subsessile, erect or ascending, stout, 8–13 mm. long; style nearly obsolete, stigma shallowly 2-lobed.

Distribution: southern Utah, western Nevada, southern California. Type: *M. E. Jones 5685* from Bromide Pass, Henry Mountains, Utah.

Specimens examined:

Utah: Bromide Pass, Henry Mountains, July 27, 1894, *Jones 5685* (Mo. Bot. Gard. Herb., U. S. Nat. Herb., and Univ. Calif. Herb.); Bromide Pass, Henry Mountains, July 27, 1894, *Jones 5655* (Mo. Bot. Gard. Herb.); Mt. Ellen Park, Henry Mountains, July 25, 1894, *Jones 5684h* (U. S. Nat. Herb.).

Nevada: Santa Rosa Mountains, July 11, 1898, *Cusick 2026* (Univ. Calif. Herb., Mo. Bot. Gard. Herb., and U. S. Nat. Herb.); Wadsworth, June 16, 1897, *Jones* (Mo. Bot. Gard. Herb. and U. S. Nat. Herb.); Reno, July, 1886, *Brandegee* (Univ. Calif. Herb.); Hunter Creek Canyon, Washoe County, July 19, 1913, *Kennedy 3038* (Mo. Bot. Gard. Herb.).

California: Providence Mountains, May 30, 1902, *Brandegee* (Univ. Calif. Herb.); San Bernardino Mountains, above Cushenberry Springs, June, 1886, *S. B. & W. F. Parish 1492* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.); San Bernardino Mountains,

June 17, 1894, *Parish 3034* (U. S. Nat. Herb.); northern slope San Bernardino Mountains, June 15, 1895, *Parish 3777* (U. S. Nat. Herb. and Univ. Calif. Herb.); San Antonio Mountains, June 20–22, 1899, *Hall 1252* (Univ. Calif. Herb.).

8. **C. crassicaulis** (Torr.) Wats. Bot. King's Exp. 27. 1871; Coville, Contr. U. S. Nat. Herb. 4: 62. 1893; Jones, Zoe 3: 283. 1893; Robinson in Gray, Syn. Fl. N. Am. 1[1]: 173. 1895; Howell, Fl. Northwest Am. 48. 1897; Nelson in Coulter & Nelson, Manual Cent. Rocky Mountains, 210. 1909; Rydb. Fl. Rocky Mountains, 364. 1917.

Streptanthus crassicaulis Torr. Stansbury's Exp. 383 *t. 1.* 1852; Walp. Ann. 3: 192. 1857; Gray, Proc. Am. Acad. 6: 186. 1866.

Caulanthus senilis Heller, Muhlenbergia 8: 137. *t. 16.* 1913.

Short-lived perennial, leaves and stem glabrous and glaucous: stems erect, unbranched, stout, more or less inflated, hollow, 3–10 dm. high: radical leaves rosulate, the primary oblanceolate, subentire or sinuate-dentate, 3–5 cm. long; secondary radical- and lowermost stem-leaves deeply and irregularly lyrate or runcinate, 5–15 cm. long; upper stem-leaves few, nearly linear; sepals purplish, densely hirsute, not saccate at the base, nearly equal in length, scarious-margined, dorso-ventral pair narrower than the lateral, 10–15 mm. long; petals purplish or brownish (at least in dried material), broadly linear, channelled, curved outwards, 15–20 mm. long; filaments linear, tetradynamous, 6–9 mm. long, anthers broadly apiculate, about 5 mm. long: inflorescence racemose; pedicels very stout, 3–5 mm. long, ascending, more or less hirsute: pods erect or ascending, rather stout, 10–13 cm. long, subsessile; style nearly obsolete, stigma broadly 2-lobed, lobes nearly 1 mm. long.

Distribution: southwestern Wyoming, southern Idaho, Utah, Nevada. Type: *Stansbury* from "mountain side on the east shore of Salt Lake," Utah.

Specimens examined:

Idaho: Mrs. Foote's Mesa, June 19, 1892, *Mulford* (Mo. Bot. Gard. Herb.).

Utah: Richfield, June 5, 1875, *Ward 177* (Mo. Bot. Gard. Herb.); Price, June 20, 1898, *Stokes* (Univ. Calif. Herb.).

Nevada: Palisade, June 14, 1882, *Jones 3776* (Mo. Bot. Gard. Herb.); east of Carson Lake, June 3, 1859, *H. Engelmann 78* (Mo. Bot. Gard. Herb.); White Mountains near Sunland, Mineral County, June 25, 1912, *Heller 10506* (U. S. Nat. Herb.); Mil-

ler Mountain, Esmeralda County, June 6, 1882, *Shockley 252* (Univ. Calif. Herb. and Mo. Bot. Gard. Herb.); Gold Mountain, May–Oct., 1898, *Purpus 5992* (Univ. Calif. Herb.); Good Springs, Clark County, May, 1915, *K. Brandegee* (Univ. Calif. Herb.); Furber, June 9, 1891, *Jones* (Univ. Calif. Herb. and Mo. Bot. Gard. Herb.).

California: Nelson Range, Inyo County, May 23, 1906, *Hall & Chandler 7160* (Univ. Calif. Herb.).

8a. Var. **glaber** Jones, Zoe 4: 266. 1893; Robinson in Gray, Syn. Fl. N. Am. 1¹: 173. 1895.

C. glaber Rydb. Fl. Rocky Mountains, 364. 1917.

As in the type except for the glabrous or nearly glabrous sepals and pedicels. Of this variety Prof. Jones says: "During the present year (1893) I have seen this occasionally in eastern Nevada along with the species. It is quite striking but passes into the type."

Distribution: southern Utah and eastern Nevada. Type: *Jones* from "summit near Sink Valley, S. Utah at 7000 ft. altitude."

Specimen examined:

Utah: "S. Utah," 1877, *Palmer 24* (U. S. Nat. Herb.).

From observation in the field Prof. M. E. Jones says of the species: "The four stamens are declined and closely pressed to the lower petals, and the two others are as tightly pressed to the upper petals." According to the same author this plant grows in "loose soil in alkaline valleys as well as in better drained localities with little alkali."

9. C. Cooperi (Wats.) Payson, n. comb.

Thelypodium Cooperi Wats. Proc. Am. Acad. 12: 246. 1877; Coville, Contr. U. S. Nat. Herb. 4: 62. 1893; Robinson in Gray, Syn. Fl. N. Am. 1¹: 174. 1895.

Guillenia Cooperi Greene, Leafl. Bot. Obs. & Crit. 1: 228. 1906.

Annual, glabrous or short and very sparingly pubescent, somewhat glaucous: stem slender, flexuous or even serpentine, simple or branched above the base, 2–6 dm. long; the lowermost stem-leaves oblong to oblanceolate, narrowed to a broad petiole, entire or sinuate-lobed, obtuse, 2–6 cm. long; other stem-leaves sagittate, mostly entire, acute: sepals usually greenish, nearly equal, 6–7 mm. long, scarcely saccate; petals pale yellow, linear-

spatulate, 2–3 mm. longer than the sepals; filaments linear, about 4 mm. long, anthers about 2 mm. long: inflorescence lax, racemose; pedicels stout, recurved, 1–3 mm. long: pods deflexed, terete, glabrous or short-pubescent, 2–4.5 cm. long, sessile; style 1–2 mm. long, stigma small, shortly 2-lobed: cotyledons oblique with respect to the radicle in the seed.

Distribution: southern Nevada, western Arizona, and southern California. Type: *Cooper* from "near Ft. Mojave," California.

Specimens examined:

Arizona: Chloride, April 15, 1903, *Jones* (Mo. Bot. Gard. Herb.).

Nevada: Muddy Range, April 10, 1905, *Goodding 2226* (Rky. Mt. Herb.).

California: Shepherd's Canyon, May 1, 1897, *Jones* (Mo. Bot. Gard. Herb.); near Laws, Inyo County, May 5, 1906, *Heller 8184* (Mo. Bot. Gard. Herb.); Nelson Range, near Lee Well, Inyo County, May 23, 1906, *Hall & Chandler 7131* (Univ. Calif. Herb.); Pleasant Canyon, Panamint Mountains, May 10, 1906, *Hall & Chandler 6942* (Univ. Calif. Herb.); Randsburg, Kern County, April 14, 1905, *Heller 7680* (Mo. Bot. Gard. Herb.); San Felipe, San Diego County, April 16, 1895, *Brandegee* (Univ. Calif. Herb.); Cottonwood Mountains, Colorado Desert, May 11, 1905, *Hall 6023* (Univ. Calif. Herb.); Colorado Desert, April, 1905, *Brandegee* (Univ. Calif. Herb.); southwestern part of Colorado Desert, April, 1887, *Orcutt* (Mo. Bot. Gard. Herb.).

When Dr. Greene placed this species in his genus *Guillenia* he recognized its affinity to *C. lasiophyllus* and its allies. He did, however, suggest that it might be a generic monotype. Considering Greene's concept of the limited amount of divergence to be allowed within a genus, his suggestion seems quite pertinent and quite in accord with the present author's views. *C. Cooperi* is somewhat intermediate between the *lasiophyllus* group (*Guillenia*) and the *Coulteri* group. Were each group thought worthy of generic rank then *C. Cooperi* would become, perhaps, a monotypic genus connecting them. To the author's mind the existence of this intermediate species argues against such a possible generic segregation.

Thelypodium deserti Jones (Contr. to Western Botany 12: 1. 1908) is unknown to the author, but to judge from the description is apparently to be associated with *C. Cooperi*. That it is not specifically identical with it there seems no doubt. This

plant was collected by M. E. Jones in the Amargosa Desert of southwestern Nevada and is described as follows: "A weak and erect annual, much branched and stems tortuous but not climbing; racemes long and loose; lowest leaves 1–3 inches long with simple and linear lobes and petioled, the rest linear and entire; the whole plant except the very base is a loose inflorescence with straggling racemes; flowers minute, purplish-white, 1 line long, calyx ashy and equalled by the slender and indifferently spreading pedicel which in fruit elongates to 2 lines long; pods 6–9 lines long, acute at each end, arcuate, torulose, 1–2 lines wide, apex very blunt; whole plant nearly smooth. This has undoubtedly been mistaken for *Streptanthus longirostris.*"

10. C. simulans Payson, n. sp.[1]

Annual, densely short-hirsute below, sparingly so above, more or less glaucous: stem much branched from near the base and upwards, 3–4 dm. high (in specimens seen): radical leaves unknown; lower cauline leaves oblong, ovate or lanceolate, sparsely short-hirsute, especially on the margins and the midrib, sessile, sagittate at the base, subentire or sinuate-dentate, 2–4 cm. long; upper cauline leaves usually acute, entire or subentire, somewhat reduced: sepals yellowish, neither pair at all saccate, 5–6 mm. long, dorso-ventral pair narrower and slightly longer, sparsely hirsute; petals whitish, broadly linear or narrowly spatulate, somewhat crisped, 8–10 mm. long; filaments tetradynamous, linear, sparsely hirsute, 3.5–4.5 mm. long, anthers not apiculate, about 2 mm. long: inflorescence racemose; pedicels hirsute, somewhat recurved, 3–5 mm. long, rather stout: pods straight, divaricate-descending, terete, sessile, glabrous, 4–6.5 cm. long; style less than 1 mm. long, stigma definitely 2-lobed; septum thin, cells rectangular: seeds not winged, oblong, cotyledons usually obliquely accumbent, rarely completely accumbent.

Distribution: southern California.

Specimens examined:

[1]**Caulanthus simulans** sp. nov., annuus plus minusve glaucus; caule ramoso inferne hirsutulo gracile 3–4 dm. alto; foliis caulinis oblongis ovatis vel lanceolatis hirsutulis sessilibus amplexicaulibus subintegris vel integris 2–4 cm. longis; sepalis subflavis non saccatis, fere similibus 5–6 mm. longis pilosiusculis, petalis pallidis linearibus spatulisve 8–10 mm. longis, filamentis tetradynamis 3.5–4.5 mm. longis; inflorescentiis floriferis laxis racemosis, pedicellis hirsutis recurvulis 3–5 mm. longis; siliquis patento-reflexis rectis teretibus sessilibus glabris 4–6.5 cm. longis, stylo circiter 0.5 mm. longo, stigmate bilobo; seminibus immarginatis, cotyledonibus oblique incumbentibus.—Collected in Coyote Canyon, El Toro Mountain, California, May 17-June 1, 1901, *H. M. Hall 1894* (Univ. Calif. Herb., TYPE).

California: Coyote Canyon, El Toro Mountain, 5500 ft. alt., May 17–June 1, 1901, *H. M. Hall 1894* (Univ. Calif. Herb., TYPE); summit Nigger Jim Hill, Cahuilla, May 17–June 1, 1901, *Hall* (Univ. Calif. Herb.); El Toro Mountain, May, 1899, *Hall 1171* (Univ. Calif. Herb.); vicinity of Winchester, April, 1902, *Hall 2908* in part (Mo. Bot. Gard. Herb.); between Elsinore and Menifee, March, 1893, *King* (Univ. Calif. Herb.).

C. simulans finds its closest allies in *C. Cooperi, C. Coulteri,* and *C. heterophyllus.* From the first it is at once separable by the longer pods and conspicuous hirsute pubescence. From the last two the quite terete pods and yellowish flowers distinguish it. The stigma in the new species is not so deeply 2-lobed as in *C. Coulteri.* In general appearance the present species is quite similar to *Caulanthus lasiophyllus* and on that account has received its specific name.

Doubtfully referred here is a specimen collected by *Miss Eastwood* from Painted Cave Ranch, Santa Barbara, California, April 25, 1908, No. *35* (Univ. Calif. Herb.). This has quite large, light yellow flowers and sinuate-lobed, narrowly oblong, cauline leaves, 5–16 mm. long. A depauperate plant on the same sheet has much smaller flowers and leaves. Further collections may prove this distinct or increase our present notion of the plant's variability.

11. C. Coulteri Wats. Bot. King's Exp. 27. 1871; Robinson in Gray, Syn. Fl. N. Am. 1[1]: 172. 1895.

Streptanthus heterophyllus Gray, Proc. Am. Acad. 6: 185. 1866, in part.

S. Coulteri Gray in Wats. Bot. King's Exp. 19. 1871; Greene, Fl. Franciscana, 257. 1891.

Annual, more or less densely hirsute-pubescent, especially toward the base of the stem: stem erect, simple or sparingly branched, 3–7 dm. high: cauline leaves from broadly linear to oblong or oblanceolate, 4–8 cm. long, all but the lowermost amplexicaul at the base, sinuate-dentate; the upper lanceolate, subentire: sepals purple in the bud, becoming lighter or yellowish in anthesis, glabrous or hirsute, apparently very unequal in the bud, scarcely saccate, 7–15 mm. long; petals light, conspicuously veined with purple, broadly linear, crisped, much longer than the sepals; stamens in three pairs, ventral pair longest, about equalling the sepals, filaments united for about half or three-fourths their lengths, anthers 1–2 mm. long, filaments of dorsal pair somewhat shorter, free, anthers longer, filaments of solitary

stamens shortest, anthers longest: inflorescence rather lax, racemose; pedicels hirsute, reflexed, 5–10 mm. long: pods divergent-descending to pendent (rarely erect), glabrous, stout, subterete or slightly flattened, 5–10 cm. long, sessile or nearly so; style about 1 mm. long, stigma deeply 2-lobed.

Distribution: southern California. Type: *Coulter* from southern California.

Specimens examined:

California: above Pollasky, Madera County, April 11, 1906, *Heller 8135* (Mo. Bot. Gard. Herb.); Kaweah River Basin, March 31, 1902, *Hopping 270* (Univ. Calif. Herb.); hillsides near Springville, April-Sept., 1897, *Purpus 5065* (Mo. Bot. Gard. Herb.); Greenhorn Range, Kern County, June 2–10, 1904, *Hall & Babcock 5079* (Univ. Calif. Herb.); Kern Canyon, Kern County, April 26, 1905, *Heller 7768* (Mo. Bot. Gard. Herb.); hills near Caliente, Kern County, April 26–May 30, 1896, *Davy 1880* (Univ. Calif. Herb.); near Oil City, Kern County, April 8, 1905, *Heller 7630* (Mo. Bot. Gard. Herb. and Univ. Calif. Herb.); San Emidio, Kern County, March 26, 1895, *Eastwood* (Univ. Calif. Herb.); Elizabeth Lake, Los Angeles County, May 1–3, 1902, *Hall 3060* (Mo. Bot. Gard. Herb. and Univ. Calif. Herb.); Leonis Valley, Los Angeles County, May 9–24, 1896, *Davy 2636* and *2634* (Univ. Calif. Herb.).

Heller's specimen No. *7630* from near Oil City is unique among those seen in that the pods are erect. The stem is also more nearly glabrous than is usual for *C. Coulteri*. In these characters it approaches *C. Lemmonii* but the stigma is less deeply lobed than in that species. The insertion of *C. Coulteri* among the erect-podded species in the key is made because of this specimen.

12. C. Lemmonii Wats. Proc. Am. Acad. **23**: 261. 1888; Robinson in Gray, Syn. Fl. N. Am. **1**[1]: 172. 1895.

Streptanthus Parryi Greene, Fl. Franciscana, 257. 1891.

Annual, pilose on the lower leaves and towards the base of the stem, otherwise glabrous and glaucous: stem erect, simple or branched above the base, 2–8 dm. high: leaves sessile, auriculate-clasping at the base; lowermost oblanceolate or oblong, dentate, denticulate or entire, 2–10 cm. long; upper entire, sagittate, acute, smaller: calyx dark purple in the bud, fading to flesh color in anthesis, unequal, 7–15 mm. long; petals well exserted, crisped, white with dark purple veins; stamens in three pairs similar to those of *C. Coulteri*: inflorescence racemose; pedicels

frequently hispid, at length 10–20 mm. long, ascending in the bud, reflexed in anthesis and curved sharply upwards in fruit: pods subsessile, erect, glabrous, subterete or slightly compressed, 8–13 cm. long, 2–3 mm. wide; style rarely over 1 mm. long; stigma large, lobes 1.5–3 mm. long; cells of the septum rectangular, short: seeds not winged.

Distribution: western California in the counties of Monterey and San Luis Obispo. Type: *J. G. & S. A. Lemmon* from "near Cholame, northeastern part of San Luis Obispo County."

Specimens examined:

California: 1888, *Parry* (Mo. Bot. Gard. Herb.); Paso Robles, April 9, 1899, *Barber* (U. S. Nat. Herb.); Paso Robles, Nov. 7, 1899, *Barber* (Univ. Calif. Herb.); Paso Robles, May 1, 1903, *Grant 146a* (Univ. Calif. Herb.).

13. C. heterophyllus (Nutt.) Payson, n. comb.

Streptanthus heterophyllus Nutt. in Torr. & Gray, Fl. N. Am. 1: 77. 1838; Walp. Rep. 1: 129. 1842; Dietr. Syn. Pl. 3: 730. 1843; Gray, Proc. Am. Acad. 6: 185. 1866, in part; Wats. Bot. King's Exp. 430. 1871; Greene, Fl. Franciscana, 257. 1891; Wats. in Gray, Syn. Fl. N. Am. 1[1]: 169. 1895; Abrams, Fl. of Los Angeles and Vicinity, 167. 1904, and ed. 2, 152. 1917.

Annual, more or less hirsute-pubescent, especially towards the base: stem erect, simple or sparingly branched, 3–10 dm. high: leaves broadly linear or linear-lanceolate, pinnatifid with divaricate lobes, sinuate-dentate or subentire, all but the lowermost sagittate at the base, 3–12 cm. long: sepals purple, linear-lanceolate, not saccate, nearly equal, about 9 mm. long; petals pale with purple veining, linear, recurved, 12–14 mm. long; filaments linear, nearly equal, distinct, about 4.5 mm. long, anthers 3 mm. long, not apiculate: inflorescence lax, racemose; pedicels recurved or refracted, hirsute, 4–8 mm. long: pods pendent, straight, somewhat compressed, glabrous, 5–8 cm. long, 1.5–2 mm. wide, subsessile; style about 2 mm. long, stigma shallowly 2-lobed: seeds narrowly winged, cotyledons oblique.

Distribution: southern California. Type: *Nuttall* from "St. Diego, upper California."

Specimens examined:

California: Soledad, March 28, 1882, *Jones 3129* (Mo. Bot. Gard. Herb.); Soledad, 1882, *Parry* (Mo. Bot. Gard. Herb.); hillside, Los Angeles County, April, 1890, *Hasse* (Mo. Bot. Gard. Herb.); Del Mar Heights, March 24, 1895, *Angier 79* (Mo. Bot.

Gard. Herb.); sand bluffs of the sea-shore, San Diego County, April 25, 1882, *Pringle* (Mo. Bot. Gard. Herb.); Rose Canyon, La Jolla, March 6, 1914, *Clements & Clements 30* (Mo. Bot. Gard. Herb.); San Diego, 1882, *Parry* (Mo. Bot. Gard. Herb.); Encanto, 1882, *Parry* (Mo. Bot. Gard. Herb.); San Diego, April 25, 1903, *Brandegee 3390* (Mo. Bot. Gard. Herb.); lower hills, San Bernardino Mountains, March and April, 1888, *S. B. & W. F. Parish* (Mo. Bot. Gard. Herb.).

Although carried for many years as a species of *Streptanthus* this plant has frequently been confused with other plants now considered members of the genus *Caulanthus*. *C. Coulteri*, for instance, was first segregated from material identified at one time by Dr. Gray as *S. heterophyllus*. In one place (Proc. Am. Acad. **6**: 186) he remarks on the difference in the stigmas of these two plants but allows that much intraspecific variation. In the 'Flora Franciscana' Dr. Greene associates this plant with *Streptanthus Coulteri* and *S. Parryi* (*C. Lemmonii*). Both of those plants have been retained in *Caulanthus* for many years. The present plant, *C. heterophyllus*, has previously been retained in *Streptanthus* for two main reasons: it has pods that are somewhat compressed and seeds that are narrowly margined. This is taken to mean that *C. heterophyllus* shows a parallel development to what occurs in *Streptanthus*. From a phylogenetic standpoint it is out of place in *Streptanthus*, since it is undoubtedly derived from existing species of *Caulanthus*—or a species very similar to existing ones—and not from the same point that it is believed *Streptanthus* has developed.

14. C. californicus (Wats.) Payson, n. comb.

Stanfordia californica Wats. Geol. Survey Calif. Bot. **2**: 479. 1880; Prantl in Engler & Prantl, Nat. Pflanzenfam. III. Abt. 2: 206. 1891; Robinson in Gray, Syn. Fl. N. Am. 1^1: 171. 1895; Hayek, Beih. Bot. Centralbl. 27^1: 314. 1911.

Streptanthus californicus Greene, Fl. Franciscana, 256. 1891.

Annual, glabrous or very sparingly pilose near the base: stem erect, branched from near the base and upwards, 2–4 dm. high: radical leaves oblanceolate, sinuately lobed to pinnatifid, obtuse, 3–6 cm. long; cauline leaves ovate to oblong, amplexicaul, shallowly dentate, obtuse: sepals purple-tipped, unequal, membranous and saccate near the base, 7–9 mm. long; petals whitish, little longer than the sepals, claw dilated, blade small, crisped; filaments 5–9 mm. long, longer pair sometimes slightly united

at the base, anthers 2–3 mm. long, apiculate: inflorescence lax, racemose; pedicels pilose, curved, ascending or somewhat deflexed, 5–10 mm. long: pods ascending or deflexed, straight, 2–4 cm. long, 2–3 mm. wide, slightly compressed or quadrangular, subsessile; style 2–7 mm. long, stigma deeply 2-lobed: cotyledons in seed obliquely incumbent, 3-parted.

Distribution: south central California. Type: *Mrs. Bush* from "near Tulare."

Specimen examined:

California: Delano, May, 1888, *Eisen* (Mo. Bot. Gard. Herb.).

Stanfordia as a genus is practically dependent upon one character: the deeply trifid cotyledons, which are remarkable and without parallel in the genus *Caulanthus*. No tendency in this direction has ever been noticed in any of the other species. In other respects, however, *C. californicus* is a true *Caulanthus*. Only in very minor ways does it differ from its nearest relative, *C. Coulteri*. The pods are much shorter but their variable position from erect to deflexed is very suggestive of this group. The stamens are sometimes united at the base as in *C. Coulteri*. The sepals are more definitely inflated and the petals differently shaped, but these differences are no greater than between other species of *Caulanthus*. The habit and general appearance of the plant are so similar to its relatives in the present genus that an examination of the cotyledons would be necessary definitely to locate it for any one not perfectly familiar with the species. The author does not believe that one character is enough upon which to base a genus, particularly a monotypic genus, unless there is some reason to question its point of origin. This plant undoubtedly arose from *C. Coulteri* or a close relative of it, and so for the sake of simplicity the genus *Stanfordia* is merged in *Caulanthus*.

15. C. stenocarpus Payson, n. sp.[1]

Annual, more or less densely hirsute-pubescent with flattened trichomes: stem erect, slender, simple or sparingly branched,

[1]**Caulanthus stenocarpus** sp. nov., annuus plus minusve hirsuto-pubescens; caule erecto gracile ramuloso 3–4 dm. alto; foliis caulinis lineari-lanceolatis subintegris sessilis amplexicaulibus 1–2 cm. longis; floribus pendentibus, sepalis non saccatis similibus circiter 4 mm. longis, petalis purpurellis late linearibus 6 mm. longis, filamentis distinctis 3–4 mm. longis; inflorescentiis serius laxis racemosis, pedicellis recurvis hirsutis 1–2 mm. longis; siliquis teretibus rectis patento reflexis glabris aut hispidulis, stylo 1–2 mm. longo, stigmate parvo subintegro; seminibus immarginatis, cotyledonibus oblique incumbentibus.—Collected on dry hillsides near Bernardo, California, May 1, 1903, *LeRoy Abrams 3364* (Mo. Bot. Gard. Herb., TYPE).

3–4 dm. high: cauline leaves few, the uppermost linear-lanceolate, subentire, sagittate at the base, 1–2 cm. long: flowers pendent; sepals purple, linear-lanceolate, not saccate, nearly equal, glabrous or nearly so, about 4 mm. long; petals at least veined with purple, broadly linear, about 6 mm. long; filaments distinct, about 3 mm. long, anthers not apiculate, about 1 mm. long: inflorescence lax, racemose; pedicels recurved, 1–2 mm. long, hirsute: pods divaricate-descending or pendent, straight, terete or slightly quadrangular, 2–4.5 cm. long, 1 mm. or less wide, sparsely retrose-pubescent with flattened trichomes, or glabrous, sessile; septum dense, cell-walls tortuous, closely compacted; style 1–2 mm. long, slightly tapering from base to apex, stigma small, nearly entire: seeds not winged, embryo purple, cotyledons obliquely incumbent.

Distribution: San Diego County, southern California.

Specimen examined:

California: dry hillsides near Bernardo, May 1, 1903, *Abrams 3364* (Mo. Bot. Gard. Herb., TYPE).

This species is known from but a single specimen which has only one fragmentary flower and a few leaves. The fruits, however, are well developed and quite mature. It is to be expected that the measurements given in the specific description, especially of the floral parts, will probably not be found sufficiently inclusive for the entire specific variation. The type was distributed as *Streptanthus heterophyllus* but the new species is very different from that by virtue of the short, terete pods. Its closest ally is perhaps *C. simulans*. From this it differs markedly by the small, entire stigma and the dense septum. The character of this septum is quite different from any other species of *Caulanthus* except *C. lasiophyllus*.

16. Caulanthus flavescens (Hook.) Payson, n. comb.

Streptanthus flavescens Hook. Icones 1: *t. 44*. 1837; Torr. & Gray, Fl. N. Am. 1: 77. 1838; Hook. & Arn. Bot. Beechey's Voy. 322. 1841; Walp. Rep. 1: 129. 1842; Dietr. Syn. Pl. 3: 730. 1843; Torr. Pac. Rail. Rept. 4: 65. 1856; Gray, Proc. Am. Acad. 6: 186. 1866, in part; Wats. Bot. King's Exp. 430. 1871.

S. procerus Brewer, Proc. Am. Acad. 6: 519. 1866.

Thelypodium flavescens Wats. Bot. King's Exp. 25. 1871, not Jepson; Brewer & Wats. Geol. Survey Calif. Bot. 1: 38. 1876; Greene, Fl. Franciscana, 263. 1891; Robinson in Gray, Syn. Fl. N. Am. 1[1]: 177. 1895.

Caulanthus procerus Wats. Bot. King's Exp. 27. 1871; Robinson in Gray, Syn. Fl. N. Am. 1[1]: 173. 1895.

Thelypodium Hookeri Greene, Fl. Franciscana, 263. 1891; Robinson in Gray, Syn. Fl. N. Am. 1[1]: 177. 1895.

T. Greenei Jepson, Fl. West. Mid. Calif. 212. 1901, and ed. 2, 181. 1911.

T. flavescens Jepson, Fl. West. Mid. Calif. 212. 1901, and ed. 2, 181. 1911.

Guillenia flavescens Greene, Leafl. Bot. Obs. & Crit. 1: 228. 1906.

G. Hookeri Greene, Leafl. Bot. Obs. & Crit. 1: 228. 1906.

Annual, rather stout, glabrous and glaucous or sparsely hirsute: stems erect, simple or branching in the inflorescence, 3–12 dm. high: radical leaves petioled, blade lanceolate to oblanceolate in outline, sinuate-pinnatifid, lyrate or coarsely laciniate, 5–22 cm. long; cauline leaves sessile, shortly petioled or even slightly auriculate at the base, deeply toothed to subentire: sepals pale yellow, lanceolate, acute or acuminate, 7–11 mm. long, glabrous; petals light yellow, 9–15 mm. long, claw rather broad, blade narrow, crisped, recurved, acute or acuminate: stamens included, anthers 2.5–4 mm. long, apiculate: inflorescence rather lax, racemose from the first; pedicels rather stout, curved upwards, 5–7 mm. long: pods erect, terete or somewhat 4-angled, glabrous or sparsely hirsute, subsessile, 4–8.5 cm. long, rather stout; style tapering to the apex, 2–3.5 mm. long, stigma entire or slightly 2-lobed: seeds not winged, cotyledons usually incumbent with tip of radical more or less oblique, rarely obliquely accumbent.

Distribution: west-central California in the vicinity of San Francisco. Type: *Douglas* from Monterey.

Specimens examined:

California: May 4, 1907, *K. Brandegee* (Univ. Calif. Herb.); Collinsville, Solano County, May 30, 1893, *K. Brandegee* (Univ. Calif. Herb.); Antioch, *Brandegee* (Univ. Calif. Herb.); Byron Springs, Contra Costa County, March 14, 1914, *Eastwood 3813* (U. S. Nat. Herb.); Livermore, *Michener & Bioletti* (Univ. Calif. Herb.).

There seems no way of separating specifically the type of this species collected by Douglas at Monterey and the plant described by Watson from Benecia. Greene (Fl. Franciscana) first called attention to the generic similarity of the two plants and remarked: " . . . they are with difficulty held distinct

as species. The only difference is in the petals; and by these the present plant would stand well in *Streptanthus* if its habit and narrow, terete pods were not those of the annual Thelypods precisely." Jepson followed Greene in his interpretation of the specific limits involved. The characters used by Greene and Jepson to keep the species apart, namely relative length of the sepals and petals and glabrous or hirsute pods, will not serve since there seems to be no correlation between them. Nor do these characters correlate with leaf texture and outline. In like manner the author can find no distinguishing characteristics upon which to separate *Caulanthus procerus*.

17. C. anceps Payson, n. name.

Thelypodium Lemmoni Greene, West. Am. Scientist **3**: 156. 1887; Greene, Fl. Franciscana, 263. 1891; Robinson in Gray, Syn. Fl. N. Am. **1**[1]: 178. 1895, not *Caulanthus Lemmoni* Wats.

Annual, glabrous and glaucous or sparsely pilose near the base: stems erect, simple or sparingly branched upwards, often stout, 6–18 dm. high: radical and lower stem-leaves narrowed to a short petiole, somewhat lanceolate in general outline, sinuate-dentate, often deeply lobed near the base, 6–15 cm. long; upper leaves sessile or nearly so, narrowly lanceolate, denticulate or subentire: sepals spreading, purple, with scarious margins, oblong, obtuse, glabrous, 3–4 mm. long, the outer pair slightly exceeding the inner; petals whitish, oblanceolate, obtuse, 4–5 mm. long; filaments linear, 2.5–3 mm. long, anthers about 1.5 mm. long, not apiculate; nectar glands very small: inflorescence shortly racemose, lax, elongating at maturity; pedicels slender, at first horizontal, later either reflexed or ascending, 5–6 mm. long: pods erect or pendent, terete, glabrous or sparsely hirsute, subsessile, 3–5 cm. long; style tapering to the apex, 2–3 mm. long, stigma small, slightly 2-lobed, lobes extending over the placentae.

Distribution: western California. Type: *Mr. & Mrs. J. G. Lemmon* from Lemmon's Ranch in the mountains of San Luis Obispo County.

Specimens examined:

California: Zapato Chino Creek, March 27, 1893, *Brandegee* (Univ. Calif. Herb.); Estrella Plains, San Luis Obispo County, March 24, 1901, *Barber A7* (Univ. Calif. Herb.).

18. C. lasiophyllus (Hook. & Arn.) Payson, n. comb.

Turritis (?) lasiophylla Hook. & Arn. Bot. Beechey's Voy. 321. 1841; Walp. Rep. **1**: 130. 1842; Dietr. Syn. Pl. **3**: 689. 1843.

Sisymbrium reflexum Nutt. Proc. Acad. Phila. 4: 25. 1850; Brewer & Wats. Geol. Survey Calif. Bot. 1: 41. 1876.

S. deflexum Harvey mss. in Torr. Pac. Rail. Rept. 4: 66. 1857; Fournier, Recherches Crucifer. & Sisymbrium, 108. 1865; Gray, Proc. Am. Acad. 8: 377. 1873.

S. deflexum Harvey var. *xerophilum* Fournier, Recherches Crucifer. & Sisymbrium, 108. 1865.

Erysimum retrofractum Torr. U. S. Expl. Exp. 17: 230. 1874.

Thelypodium neglectum Jones, Am. Nat. 17: 875. 1882, in part; Greene, Bull. Torr. Bot. Club 13: 143. 1886.

T. lasiophyllum Greene, Bull. Torr. Bot. Club 13: 142. 1886; Greene, Fl. Franciscana, 264. 1891; Robinson in Gray, Syn. Fl. N. Am. 1[1]: 177. 1895; Jepson, Fl. West. Mid. Calif. 212. 1901, and ed. 2, 180. 1911; Abrams, Fl. Los Angeles and Vicinity, 166. 1904, and ed. 2, 151. 1917; Piper, Contr. U. S. Nat. Herb. 11: 298. 1906; Frye & Rigg, Northwest Fl. 179. 1912.

Sisymbrium lasiophyllum K. Brandegee, Zoe 2: 339. 1892.

Guillenia lasiophylla Greene, Leafl. Bot. Obs. & Crit. 1: 227. 1906.

Thelypodium lasiophyllum forma *xerophilum* Thell. Mitt. Bot. Mus. Zurich 83: 735. 1919.

Annual, more or less hirsute with simple or forked hairs, rarely nearly glabrous: stems erect, simple or branching above, 3–20 dm. high: leaves petioled, the lower oblanceolate or oblong, 3–15 cm. long, irregularly pinnatifid with divaricate, obtuse or acute segments which in turn are frequently toothed, upper leaves sinuate-toothed or entire, reduced: sepals oblong, about one half as long as the petals; petals white or light yellow, narrowly spatulate, about 6 mm. long; filaments linear, shorter than the petals, anthers 1–1.5 mm. long, not apiculate: inflorescence corymbose, rapidly elongating at maturity, pedicels 2–4 mm. long, at first ascending, in age usually becoming strongly recurved: pods reflexed, terete, linear, sessile or subsessile, straight or somewhat curved, 3–6 cm. long; style about 1 mm. long, stigma small, circular: seeds often apiculate, cotyledons usually more or less oblique.

Distribution: western Washington, Oregon, and California; Lower California. Type: *Douglas* from California.

Specimens examined:

Washington: sandy beach of Bellingham Bay, July 8, 1890, *Suksdorf 953* (Mo. Bot. Gard. Herb.).

Oregon: 1871, *Elihu Hall 36* (Mo. Bot. Gard. Herb.).

California: Kneeland Prairie, Humboldt County, May 1, 1918, *Tracy 4907* (Univ. Calif. Herb.); east of Alder Springs, Glenn County, May 27, 1914, *Heller 11448* (Mo. Bot. Gard. Herb. and Clokey Herb.); College City, Colusa County, 1905, *King* (Univ. Calif. Herb.); hills about Scotts Valley, Lake County, May 28–June 2, 1902, *Tracy 1730* (Univ. Calif. Herb.); Howell Mountain, Napa County, May 16, 1902, *Tracy 1500½, 1501* (Univ. Calif. Herb.); Mt. St. Helena, Napa County, April 20, 1903, *Baker 2629* (Mo. Bot. Gard. Herb.); Bethany, San Joaquin County, April 27, 1903, *Baker 2791* (Mo. Bot. Gard. Herb.); Martinez, Contra Costa County, April 24, 1862, *Brewer 987* (Mo. Bot. Gard. Herb.); Mt. Diablo, March 10, 1869, *Kellogg & Harford 55* (Mo. Bot. Gard. Herb.); Berkeley, 1891, *Blasdale* (Univ. Calif. Herb.); cultivated at Berkeley, April, 1894, *Davy* (Univ. Calif. Herb.); Briones Valley, region of San Francisco Bay, March 24, 1900, *Hall 579* (Univ. Calif. Herb.); Stanford University, April, 1900, *Elmer 2350* (Mo. Bot. Gard. Herb.); Crystal Springs Lake, San Mateo County, April 6, 1902, *Baker 459* (Mo. Bot. Gard. Herb. and Rky. Mt. Herb.); Red Mountain, Santa Clara County, May, 1903, *Elmer 4340* (Mo. Bot. Gard. Herb.); back of Alum Rock Park, Santa Clara County, April 27, 1907, *Heller 8474* (Mo. Bot. Gard. Herb.); sea-side, Monterey, May 29, 1912, *Eastwood 147* (Clokey Herb.); Carmel River, Monterey County, April 16, 1903, *Heller 6586* (Mo. Bot. Gard. Herb.); Paso Robles, March 26, 1899, *Barber* (Univ. Calif. Herb.); Arroyo Grande, March, 1895, *King* (Univ. Calif. Herb.); Mojave, March 24, 1890, *Fritchy* (Mo. Bot. Gard. Herb.); Santa Barbara, May, 1902, *Elmer 3882* (Mo. Bot. Gard. Herb.); Painted Cave Ranch, near Santa Barbara, April 25, 1908, *Eastwood 35* (Mo. Bot. Gard. Herb.); Antelope Valley, 1895, *Davidson* (Univ. Calif. Herb.); Sierra Santa Monica, May, 1891, *Hasse* (Mo. Bot. Gard. Herb.); Elysian Park, Los Angeles, March 13, 1901, *Setchell* (Univ. Calif. Herb.); Playa del Rey, April, 1903, *Hall 3771* (Univ. Calif. Herb.); Garvanza, March, 1903, *Grant 1288* (Rky. Mt. Herb.); Hesperia, April 10, 1892, *Trelease* (Mo. Bot. Gard. Herb.); Hemet, Feb. 6, 1897, *Hall 358* (Univ. Calif. Herb.); vicinity of Riverside, April, 1902, *Hall 2967* (Univ. Calif. Herb.); vicinity of Winchester, April, 1902, *Hall 2759* (Univ. Calif. Herb.); Gavilan, March 20, 1897, *Hall 405* (Univ. Calif. Herb.); Los Coyotes, western borders of Colorado Desert, April, 1902, *Hall 2823* (Univ. Calif. Herb.); San Diego, March 17, 1882, *Jones*

2634 (Mo. Bot. Gard. Herb. and Clokey Herb.); San Diego, Feb. 26, 1884, *Orcutt 1024* (Mo. Bot. Gard. Herb.); San Diego, April 1, 1895, *Brandegee* (Univ. Calif. Herb.); Sweetwater Dam, near San Diego, April, 1902, *Grant 1305* (Univ. Calif. Herb.); Del Mar, March 22, 1895, *Angier 196* (Mo. Bot. Gard. Herb.); Howard Canyon, La Jolla, April 14, 1914, *Clements & Clements 29* (Univ. Calif. Herb. and Mo. Bot. Gard. Herb.); dry hillsides near Campo, May 24, 1903, *Abrams 3573* (Univ. Calif. Herb. and Mo. Bot. Gard. Herb.); Avalon, Santa Catalina Island, April, 1895, *Trask* (Mo. Bot. Gard. Herb.); Sheep Island, April 15, 1893, *Tidestrom* (Univ. Calif. Herb.).

Mexico:

Lower California: Valley of Palms, April 15, 1882, *Jones* (Mo. Bot. Gard. Herb. and Clokey Herb.); Palm Valley, April 1, 1886, *Orcutt* (Mo. Bot. Gard. Herb.); San Luis, April 18, 1889, *Brandegee* (Univ. Calif. Herb.); Cedros Island, April 2, 1897, *Brandegee* (Univ. Calif. Herb.); Natividad, April 10, 1897, *Brandegee* (Univ. Calif. Herb.); Guadalupe Island, March 10, 1897, *Brandegee* (Univ. Calif. Herb.); Guadalupe Island, 1875, *E. Palmer 4* (Univ. Calif. Herb. and Mo. Bot. Gard. Herb.); San Gregorio, Feb. 2, 1889, *Brandegee* (Univ. Calif. Herb.); San Julio, April 20, 1889, *Brandegee* (Univ. Calif. Herb.).

18a. Var. inalienus (Robinson) Payson, n. comb.

Thelypodium lasiophyllum (Hook. & Arn.) Greene var. *inalienum* Robinson in Gray, Syn. Fl. N. Am. 1[1]: 177. 1895; Abrams, Fl. Los Angeles and Vicinity, 166. 1904, and ed. 2, 151. 1917.

Sisymbrium acutangulum Brewer & Wats. Geol. Survey Calif. Bot. 1: 41. 1876, not DC.

S. acuticarpum Jones, Am. Nat. 17: 875. 1882.

Guillenia inaliena Greene, Leafl. Bot. Obs. & Crit. 1: 228. 1906.

Sparingly hirsute or nearly glabrous; pods erect or ascending, slender.

Distribution: with the species, but particularly abundant in the region near San Francisco Bay.

Specimens examined:

California: Vacaville, 1891, *Jepson* (Univ. Calif. Herb.); hills 3 miles south of Antioch, April 17, 1908, *Heller 8907* (Mo. Bot. Gard. Herb.); Brentwood, May 5, 1893, *Eastwood* (Univ. Calif. Herb.); hills near Berkeley, March 17, 1900, *Tracy 5999* (Univ. Calif. Herb.); Berkeley Hills, May 17, 1904, *Tracy 2075* (Univ.

Calif. Herb.); vicinity of Berkeley, April 26, 1907, *Walker 570* (Univ. Calif. Herb.); Lake Merced, San Francisco, April 25, 1903, *Tracy 1780* (Univ. Calif. Herb.); near San Francisco, 1868–69, *Kellogg & Harford 54* (Mo. Bot. Gard. Herb.); Marine Hospital, San Francisco, April 10, 1904, *Hall 4811* (Univ. Calif. Herb.); cliffs west of Colma, March 15, 1901, *Chandler 807* (Univ. Calif. Herb.); Stanford Univ., March, 1901, *Abrams 1147* (Mo. Bot. Gard. Herb.); Gigling Station east of Del Monte, May 11, 1903, *Heller 6709* (Rky. Mt. Herb. and Mo. Bot. Gard. Herb.); coast hills, San Luis Obispo County, May, 1884, *Summers* (Univ. Calif. Herb. and Rky. Mt. Herb.); San Luis Obispo, June, 1886, *Summers* (Univ. Calif. Herb.); San Luis Mountain, April, 1886, *Summers* (Univ. Calif. Herb.); Santa Maria, March 8, 1886, *Summers* (Univ. Calif. Herb., Mo. Bot. Gard. Herb., and Rky. Mt. Herb.); White Sulphur Springs, April, 1895, *Sonne* (Univ. Calif. Herb.).

18b. Var. rigidus (Greene) Payson, n. comb.

Thelypodium rigidum Greene, Pittonia 1: 62. 1887; Fl. Franciscana, 264. 1891.

T. lasiophyllum (Hook. & Arn.) Greene var. *rigidum* Robinson in Gray, Syn. Fl. N. Am. 1¹: 177. 1895.

Guillenia rigida Greene, Leafl. Bot. Obs. & Crit. 1: 228. 1906.

Rather stout and very rigid, 3–10 dm. high, glabrous above: pods ascending, straight or curved outwards, stout; on very short pedicels.

Distribution: north central California.

Specimens examined:

California: 4 miles east of Williams, Colusa County, April 12, 1917, *Ferris 504* (Univ. Calif. Herb. and Mo. Bot. Gard. Herb.); Collinsville, May 30, 1893, *Brandegee* (Univ. Calif. Herb.); Livermore, 1892, *Bioletti* (Univ. Calif. Herb.).

18c. Var. utahensis (Rydb.) Payson, n. comb.

Sisymbrium deflexum Gray, Bot. Ives' Rept. 6. 1860, not Harvey.

Thelypodium lasiophyllum Robinson in Gray, Syn. Fl. N. Am. 1¹: 177. 1895, in part.

T. utahense Rydb. Bull. Torr. Bot. Club 29: 233. 1902; Rydb. Fl. Colo. 167. 1906; Rydb. Fl. Rocky Mountains, 367. 1917.

Glabrous or nearly so: leaves usually thin, more or less membranous, lobes usually rounded and obtuse: pods reflexed, usu-

ally curved outwards.

Distribution: western Colorado (fide Rydberg), southern Utah, and Nevada, Arizona, southeastern California.

Specimens examined:

Utah: "southern Utah, northern Arizona, etc.," 1877. *E. Palmer 28* (Mo. Bot. Gard. Herb.); St. George, April 9, 1880, *Jones 1648* (Mo. Bot. Gard. Herb.); waste grounds, St. Thomas, May 3, 1902, *Goodding 700* (Rky. Mt. Herb. and Mo. Bot. Gard. Herb.).

Arizona: Williams Fork, March, 1876, *E. Palmer 21* (Mo. Bot. Gard. Herb.); Santa Rosa to Casa Grande, March 13–April 23, 1903, *Griffiths 4029* (Mo. Bot. Gard. Herb.); Tucson Mountains, March 13–April 23, 1903, *Griffiths 3485* (Mo. Bot. Gard. Herb.); near Dudleyville, March 13–April 23, 1903, *Griffiths 3712* (Mo. Bot. Gard. Herb.); Tucson, 1911, *Beard* (Mo. Bot. Gard. Herb.).

Nevada: Lincoln County, 1880, *Davis 52* (Mo. Bot. Gard. Herb.); Moapa, April 8, 1905, *Goodding 2191* (Rky. Mt. Herb. and Mo. Bot. Gard. Herb.).

California: near Mojave, April 24, 1905, *Heller 7751* (Mo. Bot. Gard. Herb.); plains east of Kern, April 6, 1905, *Heller 7605* (Mo. Bot. Gard. Herb.); Adelanto, Mojave Desert, April 30, 1918, *Parish 11797* (Mo. Bot. Gard. Herb.); Coyote Canyon in western borders of the Colorado Desert, April, 1902, *Hall 2786* (Univ. Calif. Herb.).

The present subspecific treatment of *C. lasiophyllus* is not to be regarded as particularly discriminative and is intended only to indicate the broad groups within specific limits which are somewhat localized geographically. It is not supposed that these "varieties" are homogeneous within themselves. They could doubtless be broken up into a number of "forms" or "races." It is doubtful, however, if much could be done in the way of further segregation in the herbarium alone and perhaps the study is one for the geneticist rather than for the taxonomist.

To emphasize the localized racial diversity of this species the following quotation is made from Dr. Greene's 'Flora Franciscana': "The common form at San Francisco is small, early flowering, and has suberect pods. In the coast range the plant is often a yard high or more, late flowering, with pods straight and strongly deflexed. On the plains east of the Mount Diablo Range grows in great abundance a plant here referred which differs in being glabrous, with pods more or less curved, often spreading only, sometimes deflexed. All these need further examination;

and *T. neglectum* may prove to be one of them." A field and garden study of this species would seem to offer a most attractive subject for investigation for the student of the region to which it is native.

It is of further interest to note that *C. lasiophyllus* is adventive in Europe. Thellung reports it from Birsfelden (Switzerland) and from Rotterdam. So far as is known this is the only member of this group of genera to become a weed. This is particularly striking because its nearest relatives are extremely restricted in their range.

Co-type material of *T. neglectum* has been examined at the Gray Herbarium. It is a mixture of *Thelypodium laciniatum* and *Caulanthus lasiophyllus*. This material was collected by M. E. Jones at Santa Cruz, California in 1881. *Sisymbrium acuticarpum* seems to belong here also. Material collected by Prof. Jones from near the type locality and labelled in his own handwriting as "*Sisymbrium* n. sp." does not differ from typical forms of the species to any considerable extent. In the type the pods were described as erect, in the material seen they are reflexed.

Two specimens at hand from Catalina Island indicate that the form there is not typical. Further collections may show it varietally distinct.

All material from interior states is more or less similar in leaf texture and lobing and has accordingly been separated as a geographical variety. It evidently intergrades frequently with the coastal plant and may not be kept specifically distinct.

STREPTANTHELLA

STREPTANTHELLA Rydb. Fl. Rocky Mountains, 364. 1917.

Glabrous, annual herbs with entire or shallowly dentate leaves and branched stems. Flowers relatively small; sepals, particularly the lateral pair, saccate at the base; petals with narrow blades; stamens distinct, anthers short, apiculate. Pods pendent on recurved pedicels, sessile, strongly compressed, narrowed at the apex to a conspicuous beak that simulates a persistent style; valves dehiscent at the base but remaining attached at the apex; septum cells at the margin somewhat elongated at right angles to the replum, in the middle elongated parallel to the replum, all more or less tortuous. Seeds flattened, narrowly winged, cotyledons oblique. Generic type: *S. longirostris* (Wats.) Rydb.

1. S. longirostris (Wats.) Rydb. Fl. Rocky Mountains, 364. 1917.

Arabis longirostris Wats. Bot. King's Exp. 17. *t. 1.* 1871; Brewer & Wats. Geol. Survey Calif. Bot. 1: 31. 1876.

Streptanthus longirostris Wats. Proc. Am. Acad. 25: 125. 1889; Wats. in Gray, Syn. Fl. N. Am. 1[1]: 170. 1895; Howell, Fl. Northwest Am. 47. 1897; Piper, Contr. U. S. Nat. Herb. 11: 296. 1906; Nelson in Coulter & Nelson, Manual Cent. Rocky Mountains, 211. 1909; Frye & Rigg, Northwest Fl. 180. 1912.

Euklisia longirostris Rydb. Bull. Torr. Bot. Club 33: 142. 1906; Rydb. Fl. Colo. 166. 1906; Wooton & Standley, Contr. U. S. Nat. Herb. 19: 269. 1915.

Guillenia rostrata Greene, Leafl. Bot. Obs. & Crit. 1: 228. 1906.

Annual, glabrous and glaucous throughout: stem usually much branched above, slender, 3–6 dm. high: leaves deciduous at maturity; lower cauline leaves narrowly oblanceolate, usually sinuate-dentate or repand, 2–5 cm. long; upper leaves linear-lanceolate to linear, mostly entire: sepals greenish or tipped with purple, the lateral pair saccate at the base, dorso-ventral pair slightly so, all nearly equal, 3–6 mm. long; petals yellowish, linear-spatulate, exceeding the sepals by about one-fourth; filaments tetradynamous, linear, about as long as the sepals, anthers apiculate, about 1 mm. long; nectar glands well developed at base of solitary stamen: inflorescence lax, shortly racemose, elongating in fruit; pedicels soon becoming recurved, slender, 2–5 mm. long: pods pendent, strongly compressed, sessile, 3–6 cm. long, 1–2 mm. wide; style very short or obsolete, stigma nearly entire: seeds narrowly winged, flat.

Distribution: southwestern to central Wyoming, western Colorado, northern New Mexico, Utah, Arizona, Nevada, southeastern Washington, eastern Oregon, eastern and southern California, and northwestern Mexico. Type: *Watson 72* from "Steamboat Springs near Washoe City, about Humboldt Lake, Nevada."

Specimens examined:

Wyoming: Alcova, Natrona County, July 1, 1901, *Goodding 159* (Mo. Bot. Gard. Herb.); sandhills in Wind River Valley, May 19, 1860, *Hayden* (Mo. Bot. Gard. Herb.); Point of Rocks, June 1, 1897, *Nelson 3082* (Mo. Bot. Gard. Herb.).

Colorado: Grand Junction, May, 1891, *Eastwood* (Bethel Herb.); Grand Junction, May, 1892, *Eastwood* (Mo. Bot. Gard. Herb.); Naturita, May 7, 1914, *Payson 280* (Mo. Bot. Gard.

Herb.); Naturita, May 15, 1914, *Payson 301* (Mo. Bot. Gard. Herb.).

New Mexico: Aztec, April, 1899, *Baker 362* (Mo. Bot. Gard. Herb.).

Utah: Diamond Valley, May 19, 1902, *Goodding 879* (Mo. Bot. Gard. Herb.); Green River, May 9, 1890, *Jones* (Mo. Bot. Gard. Herb.); near St. George, 1874, *Parry 9* (Mo. Bot. Gard. Herb.).

Arizona: mesa, Yuma, 1911, *Beard* (Mo. Bot. Gard. Herb.).

Nevada: desert near Goshoot Mountains, May 8, 1859, *H. Engelmann* (Mo. Bot. Gard. Herb.); Lincoln County, 1880, *Davis 46* (Mo. Bot. Gard. Herb.); Moapa, April 8, 1905, *Goodding 2210* (Mo. Bot. Gard. Herb.); Las Vegas, May 8, 1905, *Goodding 2324* (Mo. Bot. Gard. Herb.); Winnemucca Lake, June 3, 1913, *Kennedy 1999* (Mo. Bot. Gard. Herb.); Truckee River sands, Wadsworth, June 6, 1913, *Kennedy 2035* (Mo. Bot. Gard. Herb.).

Oregon: Umatilla, May 1, 1882, *Howell* (Mo. Bot. Gard. Herb.).

California: near Laws, May 5, 1906, *Heller 8183* (Mo. Bot. Gard. Herb.); Darwin, April 28, 1897, *Jones* (Mo. Bot. Gard. Herb.); Lancaster, June, 1902, *Elmer 3625* (Mo. Bot. Gard. Herb.).

WAREA

WAREA Nutt. Jour. Acad. Phila. **7**: 83. 1834; Torr. & Gray, Fl. N. Am. **1**: 98. 1838; Gray, Gen. Am. Bor.-Or. Ill. **1**: 155. 1848; Benth. & Hook. Gen. Pl. **1**: 80. 1862; Prantl in Engler & Prantl, Nat. Pflanzenfam. III, Abt. **2**: 155. 1891; Robinson in Gray, Syn. Fl. N. Am. **1**^{1}: 179. 1895; Small, Fl. Southeastern U. S. 487. 1903, and ed. 2, 487. 1913; Hayek, Beih. Bot. Centralbl. **27**^{1}: 180. 1911.

Erect, annual, glabrous herbs with slender, branching stems. Leaves entire, amplexicaul, sessile or cuneate at the base, all similar and none rosulate at the base of the stem. Flowers reddish purple to white, clavate in the bud; sepals equal, broadly linear or spatulate, not saccate, widely spreading or reflexed in anthesis; petals unguiculate, claw slender, blade dilated; stamens nearly equal, filaments linear, exserted, anthers revolute when dry; ovary long-stipitate. Young inflorescence contracted and corymbiform, little elongated in fruit; pedicels slender, in age deciduous at the base from the axis of the inflorescence. Pods somewhat compressed parallel to the partition, linear, falcate,

conspicuously stipitate; style very short, stigma small, subentire, the lobes evidently produced over the placentae; septum thin, cells elongated parallel to the replum, walls straight or slightly tortuous, especially near the middle. Seeds not winged, cotyledons obliquely accumbent. Generic type: *W. amplexifolia* Nutt.

Key to the Species

A. Leaves broad at the base, amplexicaul or sessile.
  a. Leaves distinctly and deeply amplexicaul at the base ---------- 1. *W. amplexifolia*
  b. Leaves sessile or subamplexicaul ---------- 2. *W. sessilifolia*
B. Leaves cuneate or subpetioled at the base.
  a. Stipe 8–11 mm. long; claws of petals papillose -- 3. *W. cuneifolia*
  b. Stipe 3–6 mm. long; claws of petals fimbriate -- 4. *W. Carteri*

1. W. amplexifolia Nutt. Jour. Acad. Phila. 7: 83. 1834, in part; Torr. & Gray, Fl. N. Am. 1: 98. 1838; Dietr. Syn. Pl. 3: 717. 1843; Robinson in Gray, Syn. Fl. N. Am. 1[1]: 180. 1895, in part; Chapman, Fl. Southern U. S., ed. 3, 28. 1897, in part; Small, Fl. Southeastern U. S. 487. 1903, and ed. 2, 487. 1913.

Stanleya amplexifolia Nutt. Am. Jour. Sci. I. 5: 297. 1822; DC. Prodr. 1: 200. 1824; Spreng. Syst. 2: 909. 1825.

Glabrous and somewhat glaucous: stems simple or paniculately branched above, 4–8 dm. tall: leaves ovate to oblong, obtuse or acute, 1.5–4 cm. long, deeply amplexicaul at the base, basal lobes rounded: flowers purplish or white; petals 7–9 mm. long, blade suborbicular, about one-half as long as the slender, slightly papillose claw: mature inflorescence 1–4 cm. long; pedicels nearly horizontal, 10–15 mm. long, deciduous: pods, including stipe, 6–7.5 cm. long (according to Nuttall), linear, curved; stipe about 10 mm. long.

Distribution: eastern Florida. Type from "East Florida" by *A. Ware.*

Specimens examined:

Florida: Tavares, Sept. 15, 1895, *Webber 20* (Mo. Bot. Gard. Herb.); pine barrens, Haines City, Aug. 14, 1897, *Curtiss 5958* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.); Clarcona, Orange County, Nov. 5, 1899, *Meislahn 36* (U. S. Nat. Herb.).

2. W. sessilifolia Nash, Bull. Torr. Bot. Club 23: 101. 1896; Small, Fl. Southeastern U. S. 487. 1903, and ed. 2, 487. 1913.

W. amplexifolia Nutt. Jour. Acad. Phila. 7: 83. *t. 10.* 1834, as to illustration and habitat.

Very similar to the preceding species, more or less glaucous: stems simple or paniculately branched above, 2–6 dm. tall: leaves ovate or ovate-lanceolate, rather thick, obtuse or acute, sessile or very slightly auriculate at the base, 1–3.5 cm. long: flowers purple, sometimes apparently pale; petals about 10 mm. long, claw slightly papillose: mature inflorescence 1–3 cm. long; pedicels divaricate, about 1 cm. long, deciduous: pods, including stipe, 2–4 cm. long; stipe 11–14 mm. long.

Distribution: western Florida. Type from "pine lands at Bellair, about 4 miles south of Tallahassee, Leon County."

Specimens examined:

Florida: Bellair, Leon County, Sept. 3, 1895, *Nash 2544* (U. S. Nat. Herb., TYPE, and Mo. Bot. Gard. Herb.); sandy pine barrens, Bristol, Oct. 25, 1895, *Mohr* (U. S. Nat. Herb.); Santa Rosa Island, Sept., 1876, *Romer* (U. S. Nat. Herb.); Santa Rosa Island, Aug. 31, 1899, *S. M. Tracy 6428* (Mo. Bot. Gard. Herb. and U. S. Nat. Herb.).

This species, although quite distinct, has been confused with *W. amplexifolia* in the past. The illustration given by Nuttall (Jour. Acad. Phila.) to illustrate that species is evidently of *W. sessilifolia.* In this publication also the habitat is given as "West Florida." It would seem that Ware collected both species but the one originally described as *W. amplexifolia* was from east Florida and in it the leaves were truly amplexicaul. That plant then must retain the name because of priority of publication. However, the plant that Nuttall really had in mind when he described the genus *Warea* was that described by Nash as *W. sessilifolia.*

3. W. cuneifolia (Muhl.) Nutt. Jour. Acad. Phila. **7**: 84. 1834; Torr. & Gray, Fl. N. Am. **1**: 98. 1838; Gray, Gen. Am. Bor.-Or. Ill. **1**: 155. *t. 66.* 1848; Robinson in Gray, Syn. Fl. N. Am. 1^1: 180. 1895, in part; Chapman, Fl. Southern U. S., ed. 3, 28. 1897, in part; Small, Fl. Southeastern U. S. 487. 1903, and ed. 2, 487. 1913, in part.

Cleome cuneifolia Muhl. Catalogue, 61. 1813, name only; Nutt. Gen. **2**: 73. 1818; DC. Prodr. **1**: 242. 1824; Elliott, Bot. South Carolina and Georgia **2**: 150. 1824; Dietr. Syn. Pl. **2**: 1068. 1840.

Stanleya gracilis DC. Syst. **2**: 512. 1821; DC. Prodr. **1**: 200. 1824; Spreng. Syst. **2**: 909. 1825.

Stems paniculately branched above, slender, 4–8 dm. tall: leaves narrowly oblong to linear-oblanceolate, 1–4 cm. long, cuneate at the base, obtuse or retuse at the apex: sepals white or purplish, linear-oblanceolate, 4–5 mm. long; petals 6–8 mm. long, blade broadly obovate, somewhat shorter than the minutely papillose claw; filaments strongly exserted: mature inflorescence not over 1.5 cm. long, pedicels slender, divaricate, 3–10 mm. long, deciduous: pods, including stipe, 3–5.5 cm. long, linear, curved; stipe slender, 8–10 mm. long.

Distribution: South Carolina and Georgia. Type from Georgia.

Specimens examined:

South Carolina: Aiken, Sept. 12–15, 1909, *Eggleston 5066* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.).

Georgia: sand-hills north of Augusta, Aug. 12, 1884, *J. D. Smith* (Mo. Bot. Gard. Herb.); sand-hills of Gum Swamp Creek, Montgomery County, Sept. 10, 1903, *Harper 1981* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.); sand-hills of Satilla River, Pierce County, Aug. 1, 1902, *Harper 1465* (Mo. Bot. Gard. Herb. and U. S. Nat. Herb.).

Nuttall in the first description of this species gives the habitat as follows: "on sandy barren grassy ridges in the southern parts of Georgia, Alabama and west Florida." In Muhlenberg's 'Catalogue,' however, where the name is published for the first time, the habitat is given as "Georgia." This would seem sufficient to identify *W. cuneifolia* as the northern plant rather than the species now known as *W. Carteri* although the original description might apply to either.

4. W. Carteri Small, Bull. Torr. Bot. Club **36**: 159. 1909; Small, Fl. Southeastern U. S. 1337. 1913.

W. cuneifolia Robinson in Gray, Syn. Fl. N. Am. **1**[1]: 180. 1895, in part; Chapman, Fl. Southern U. S., ed. 3, 28. 1897, in part; Small, Fl. Southeastern U. S. 487. 1903, in part.

Very similar to the preceding in general appearance, 5–15 dm. tall: leaves narrowly oblong to linear-oblanceolate, cuneate at the base, obtuse and frequently apiculate at the apex: sepals about 5 mm. long; petals white or nearly so, somewhat longer than the sepals, blade ovate to suborbicular, crisped, about as long as the slender, minutely fringed claws: mature inflorescence 0.5–3 cm. long, pedicels slender, divergent, 3–10 mm. long: pods

linear, curved, 3–5 cm. long (including stipe); stipe slender, 3–6 mm. long; style very short, stigma subentire.

Distribution: southern and eastern Florida. Type from "pinelands between Cutler and Black Point," collected by *Small & Carter 831.*

Specimens examined:

Florida: Miami, Nov., 1878, *Garber 26* (U. S. Nat. Herb. and Mo. Bot. Gard. Herb.); sand ridges between the ocean and Indian River, Sept., 1879, *Curtiss 171* (U. S. Nat. Herb.).

This species, according to Dr. Small, "occurs in great abundance, especially in southern peninsular Florida." It is closely related to *W. cuneifolia* and has been almost universally referred to that species in the past.

STANLEYELLA

STANLEYELLA Rydb. Bull. Torr. Bot. Club 34: 435. 1907.

Biennial glabrous herb with branching stem. Leaves entire or toothed, all narrowed at the base. Flowers white or pale purplish; sepals spreading or reflexed in anthesis, not saccate; petals short-clawed; filaments distinct, linear, folded in the bud, anthers more or less coiled at maturity. Pods terete, subsessile, or shortly stipitate; septum thin, cells more or less rectangular, not tortuous. Seeds not winged, cotyledons obliquely accumbent. Generic type: *S. Wrightii* (Gray) Rydb.

1. S. Wrightii (Gray) Rydb. Bull. Torr. Bot. Club 34: 435. 1907; Wooton & Standley, Contr. U. S. Nat. Herb. 19: 267. 1915; Rydb. Fl. Rocky Mountains, 368. 1917.

Thelypodium Wrightii Gray, Smithson. Contr. [Pl. Wright.] 3: 7. 1852, and 5: 12. 1853; Porter & Coulter, Syn. Fl. Colo. 9. 1874; Hemsley, Biol. Cent.-Am. Bot. 1: 31. 1879; Coulter, Manual Rocky Mountain Region, 21. 1885; Coulter, Contr. U. S. Nat. Herb. 1: 30. 1890, and 2: 15. 1891; Robinson in Gray, Syn. Fl. N. Am. 1¹: 177. 1895; Rydb. Fl. Colo. 167. 1906; Nelson in Coulter & Nelson, Manual Cent. Rocky Mountains, 209. 1909; Clements & Clements, Rocky Mountain Flowers, 28. 1914.

Biennial, glabrous throughout or sparingly pilose at the base: stem erect, branching, 6–15 dm. high: radical and lower stem-leaves irregularly lyrate, 1–1.5 dm. long; stem-leaves somewhat reduced upwards, irregularly toothed to subentire: sepals oblong

or broadly linear, about 5 mm. long; petals oblanceolate, short-clawed, exceeding the sepals at least one-half; filaments slightly tetradynamous, linear, 5–7 mm. long, folded in the bud, anthers about 2 mm. long, not apiculate; nectar glands well developed: inflorescence in flower corymbose, elongating in fruit; pedicels slender, horizontal or divaricate-descending, 5–10 mm. long: pods widely spreading, terete, torulose, stipe 0.5–2 mm. long; style rarely over 1 mm. long, stigma entire: seeds not winged; cotyledons obliquely incumbent or nearly accumbent.

Distribution: western Texas, southern and western Colorado, New Mexico, southern Utah and Nevada, Arizona and northwestern Mexico. Type: *Wright,* pass of the Limpio, western Texas.

Specimens examined:

Colorado: Webster Canyon, July 25, 1872, *Redfield 418* (Mo. Bot. Gard. Herb.); Canyon City, 1871, *Brandegee 351* (Univ. Calif. Herb.); Trinidad, Sept. 26, 1913, *Rose & Fitch 17515* (Mo. Bot. Gard. Herb.); Trinidad, July 20, 1918, *Osterhout 5755* (Rky. Mt. Herb.); San Luis Valley, Sept., 1875, *Brandegee* (Mo. Bot. Gard. Herb.); Pitkin County, July 20–30, 1900, *Mann* (Mo. Bot. Gard. Herb.); Durango, July 18, 1898, *Baker, Earle & Tracy 510* (Mo. Bot. Gard. Herb. and Rky. Mt. Herb.).

New Mexico: White Mountains, Lincoln County, July 22, 1897, *Wooton 194* (Rky. Mt. Herb. and Mo. Bot. Gard. Herb.); Gray, Lincoln County, July 22, 1898, *Skehan 42* (Mo. Bot. Gard. Herb.); Gray, Lincoln County, July, 1900, *Earle & Earle 158* (Mo. Bot. Gard. Herb.); Organ Mountains, Oct. 18, 1903, *Wooton* (Rky. Mt. Herb.); Mogollon Mountains, Aug., 1881, *Rusby 26* (Mo. Bot. Gard. Herb.); Mogollon Mountains, Aug. 5, 1903, *Metcalfe 385* (Mo. Bot. Gard. Herb. and Rky. Mt. Herb.); Tularosa Creek, Sacramento Mountains, Aug. 20, 1899, *Wooton* (Mo. Bot. Gard. Herb.); on mountains at the Copper Mines, Aug., 1851, *Wright 845* (Mo. Bot. Gard. Herb.); near Silver City, July 18, 1880, *Greene* (Mo. Bot. Gard. Herb.).

Utah: Cane Spring Mountains, May–Oct. 1898, *Purpus 6231* (Rky. Mt. Herb. and Univ. Calif. Herb.).

Arizona: Prescott, Oct. 28, 1917, *Bethel* (Bethel Herb.); Prescott, Aug. 28, 1894, *Toumey* (Univ. Calif. Herb.); Pigeon Creek, Aug. 4, 1912, *Goodding 1276* (Rky. Mt. Herb.).

Nevada: Calientes, May 24, 1902, *Goodding 945* (Rky. Mt. Herb. and Mo. Bot. Gard. Herb.).

Mexico:

Lower California: Topo, Sept. 8, 1884, *Orcutt 945* (Mo. Bot. Gard. Herb. and Univ. Calif. Herb.).

1a. Var. tenellum (Jones) Payson, n. comb.

Thelypodium Wrightii Gray var. *tenellum* Jones, Proc. Calif. Acad. II. 5: 622. 1895.

Stems slender, leaves very thin, entire or with rounded lobes; inflorescence in fruit much elongated; pods very slender, torulose, 4–6 cm. long.

Distribution: Utah. Type: *M. E. Jones 5559* from Provo.

Specimens examined:

Utah: Provo Slate Canyon, July, 1894, *Jones 5559* (Mo. Bot. Gard. Herb., Rky. Mt. Herb., and Univ. Calif. Herb.).

List of Exsiccatae

In the following index to the specimens cited the collector's number, if one occurs, is printed in italics and is followed immediately by a number in parenthesis. The latter number indicates the serial number of the species involved as adopted in the present study. The name of this species follows the parenthesis. Generic abbreviations are as follows: C. (Caulanthus); Ch. (Chlorocrambe); Stan. (Stanleyella); Strep. (Streptanthella); T. (Thelypodium) and W. (Warea).

Abrams, LeRoy.
1147 (**18a**) C. lasiophyllus var. inalienus; *2699* (**1**) C. amplexicaulis; *3364* (**15**) C. stenocarpus; *3573* (**18**) C. lasiophyllus.

Angier, B. S.
79 (**13**) C. heterophyllus; *196* (**18**) C. lasiophyllus.

Austin, R. M.
(**4**) T. Howellii.

E. N. B.
(**14a**) T. lilacinum var. subumbellatum.

Baker, C. F.
362 (**1**) Strep. longirostris; *459* (**18**) C. lasiophyllus; *635* (**14**) T. lilacinum; *1020* (**10b**) T. laciniatum var. milleflorum; *1191* and *1218* (**3**) T. crispum; *2629, 2791* (**18**) C. lasiophyllus; (**7**) T. sagittatum.

Baker, C. F., Earle, F. S. & Tracy, S. M.
510 (**1**) Stan. Wrightii.

Baker, H. P.
(**14**) T. lilacinum.

Baker, M. S. & Nutting, F.
(**3**) T. crispum; (**4**) T. Howellii.

Barber, J. H.
A7 (**17**) C. anceps; (**18**) C. lasiophyllus; (**12**) C. Lemmonii.

Beard, A.
(**18c**) C. lasiophyllus var. utahensis; (**1**) Strep. longirostris.

Bennitt, D.

39, 156 (**10**) T. laciniatum.

Bethel, E.
(**1**) Stan. Wrightii; (**9**) T. flexuosum; (**11**) T. rhomboideum.

Bioletti, F. T.
(**18b**) C. lasiophyllus var. rigidus.

Blankinship, J. W.
(**14a**) T. lilacinum var. subumbellatum.

Blasdale, W. C.
(**18**) C. lasiophyllus.

Bolander, H. N.
6272 (**3**) T. crispum.

Brandegee, K.
(**8**) C. crassicaulis; (**16**) C. flavescens.

Brandegee, T. S.
351 (**1**) Stan. Wrightii; *377* (**10**) T. laciniatum; *636* (**12**) T. integrifolium; *637* (**10b**) T. laciniatum var. milleflorum; *638* (**4**) T. Howellii; *821* (**14**) T. lilacinum; *3390* (**13**) C. heterophyllus; *4278* (**11a**) T. rhomboideum var. gracilipes; (**16**) C. flavescens; (**7**) C. major; (**3**) C. inflatus; (**9**) C. Cooperi; (**17**) C. anceps; (**18**) C. lasiophyllus; (**18b**) C. lasiophyllus var. rigidus; (**1**) Stan. Wrightii; (**3**) T. crispum.

Brewer, W. H.
987 (**18**) C. lasiophyllus.

Brown, H. E.
469 (**2**) T. brachycarpum.

Burglehaus, F. H.
(**14a**) T. lilacinum var. subumbellatum.

Butler, G. D.
1850 (**2**) T. brachycarpum.

Carlton, E. C. & Garrett, A. O.
6705 (**14**) T. lilacinum.

Chandler, H. P.
807 (**18a**) C. lasiophyllus var. inalienus.

Chestnut & Drew.
(**3**) T. crispum.

Clements, F. E. & E. S.
29 (**18**) C. lasiophyllus; *30* (**13**) C. heterophyllus.

Clute, W. N.
82 (**11**) T. rhomboideum.

Cotton, J. S.
391 (**10b**) T. laciniatum var. milleflorum; *874* (**12**) T. integrifolium.

Crandall, C. S.
(**14**) T. lilacinum.

Curtiss, A. H.
171 (**4**) W. Carteri; *5958* (**1**) W. amplexifolia.

Cusick, W. C.
1618 (**4**) T. Howellii; *1884* (**9**) T. flexuosum; *1955* (**10b**) T. laciniatum var. milleflorum; *2026* (**7**) C. major; *2292* (**1**) Ch. hastata; *2541, 2546* (**5**) C. pilosus; *2694* (**12**) T. integrifolium; *2735, 2813* (**4**) T. Howellii.

Davidson, A. A.
(**3**) C. inflatus; (**18**) C. lasiophyllus.

Davis, P. W.
46 (**1**) Strep. longirostris; *52* (**18c**) C. lasiophyllus. var. utahensis.

Davy, J. B.
1880 (**11**) C. Coulteri; *2272* (**3**) C. inflatus; *2469, 2563* (**1**) C. amplexicaulis; *2634, 2636* (**11**) C. Coulteri; (**18**) C. lasiophyllus.

Eastwood, A.
35, in part (**18**) C. lasiophyllus; *35*, in part (**10**) C. simulans; *147* (**18**) C. lasiophyllus; *3813* (**16**) C. flavescens; (**11**) C. Coulteri; (**3**) C. inflatus; (**18a**) C. lasiophyllus var. inalienus; (**14**) T. lilacinum; (**1**) Strep. longirostris.

Earle, F. S. & Earle, E. S.
158 (**1**) Stan. Wrightii.

Eggleston, W. W.
5066 (**3**) W. cuneifolia.
Eisen, G.
(**14**) C. californicus.
Elmer, A. D. E.
1073 (**12**) T. integrifolium; *2350* (**18**) C. lasiophyllus; *3625* (**1**) Strep. longirostris; *3882, 4340* (**18**) C. lasiophyllus.
Engelmann, G.
(**2**) T. brachycarpum; (**14**) T. lilacinum; (**11**) T. rhomboideum.
Engelmann, H.
77 (**9**) T. flexuosum; *78* (**8**) C. crassicaulis; *110* (**14**) T. lilacinum; *111* (**11**) T. rhomboideum; (**5**) C. pilosus; (**1**) Strep. longirostris; (**10b**) T. laciniatum var. milleflorum; (**14**) T. lilacinum.
Ferris, R. S.
504 (**18b**) C. lasiophyllus var. rigidus.
Fritchy.
(**18**) C. lasiophyllus.
Garber, A. P.
26 (**4**) W. Carteri.
Goodding, L. N.
159 (**1**) Strep. longirostris; *700* (**18c**) C. lasiophyllus var. utahensis; *879* (**1**) Strep. longirostris; *945* (**1**) Stan. Wrightii; *1085* (**7**) T. sagittatum; *1276* (**1**) Stan. Wrightii; *1466* (**7**) T. sagittatum; *1789* (**11**) T. rhomboideum; *2191* (**18c**) C. lasiophyllus var. utahensis; *2210* (**1**) Strep. longirostris; *2226* (**9**) C. Cooperi; *2324* (**1**) Strep. longirostris.
Grant, G. B.
146a (**12**) C. Lemmonii; *1288, 1305* (**18**) C. lasiophyllus.
Greene, E. L.
803 (**10**) T. laciniatum; *846* (**2**) T. brachycarpum; (**1**) Stan. Wrightii..
Griffiths, D.
3485, 3712, 4029 (**18c**) C. lasiophyllus var. utahensis; *4058* (**2**) C. sulfureus.
Hall, E.
34 (**10**) T. laciniatum; *36* (**18**) C. lasiophyllus.
Hall, E. & Harbour, J. P.
51 (**14**) T. lilacinum.
Hall, H. M.
358, 405, 579 (**18**) C. lasiophyllus; *918* (**1**) C. amplexicaulis; *1165* (**6**) C. Hallii; *1171* (**10**) C. simulans; *1252* (**7**) C. major; *1436* (**1**) C. amplexicaulis; *1894* (**10**) C. simulans; *1902* (**6**) C. Hallii; *2759* (**18**) C. lasiophyllus; *2786* (**18c**) C. lasiophyllus var. utahensis; *2823* (**18**) C. lasiophyllus; *2908*, in part (**10**) C. simulans; *2967* (**18**) C. lasiophyllus; *3060* (**11**) C. Coulteri; *3101* (**1**) C. amplexicaulis; *3771* (**18**) C. lasiophyllus; *4811* (**18a**) C. lasiophyllus var. inalienus; *6023* (**9**) C. Cooperi; (**10**) C. simulans.
Hall, H. M. & Babcock, E. B.
4092 (**2**) T. brachycarpum; *5079* (**11**) C. Coulteri.
Hall, H. M. & Chandler, H. P.
6862 (**3**) C. inflatus; *6942* (**9**) C. Cooperi; *7100* (**5**) C. pilosus; *7131* (**9**) C. Cooperi; *7160* (**8**) C. crassicaulis; *7206* (**5**) C. pilosus; *7226* (**10**) T. laciniatum; *7284* (**3**) T. crispum.
Harper, R. M.
1465, 1981 (**3**) W. cuneifolia.
Hasse, H. E.
(**13**) C. heterophyllus; (**3**) C. inflatus; (**18**) C. lasiophyllus.
Hayden, F. V.
(**1**) Strep. longirostris; (**14**) T. lilacinum; (**7a**) T. sagittatum var. crassicarpum.
Heller, A. A.
6586 (**18**) C. lasiophyllus; *6709* (**18a**) C. lasiophyllus var. inalienus; *7605* (**18c**) C. lasiophyllus var. utahensis; *7630* (**11**) C. Coulteri; *7680* (**9**) C. Cooperi; *7702, 7724* (**3**) C. inflatus; *7751* (**18c**) C. lasiophyllus var. utahensis; *7768* (**11**) C. Coulteri; *8011* (**2**) T. brachycarpum; *8135* (**11**) C. Coulteri; *8183* (**1**) Strep. longirostris; *8184* (**9**) C. Cooperi; *8193* (**4**) C. glaucus;

8262 (**10**) T. laciniatum; *8295* (**5**) C. pilosus; *8474* (**18**) C. lasiophyllus; *8907* (**18a**) C. lasiophyllus var. inalienus; *9958* (**11**) T. rhomboideum; *10506* (**8**) C. crassicaulis; *11448* (**18**) C. lasiophyllus.

Heller, A. A. & Heller, E. G.
3022 (**10**) T. laciniatum.

Heller, A. A. & Kennedy, P. B.
8671 (**3**) T. crispum.

Henderson, L. F.
73 (**10**) T. laciniatum; *3248* (**7**) T. sagittatum.

Hillman, F. H.
(**11**) T. rhomboideum.

Hopping, R.
270 (**11**) C. Coulteri.

Howell, J.
(**10**) T. laciniatum.

Howell, T.
345 (**1**) T. eucosum; (**1**) Strep. longirostris.

Jepson, W. L.
(**18a**) C. lasiophyllus var. inalienus.

Johnston, E. L.
598 (**14**) T. lilacinum.

Jones, M. E.
1358 (**1**) Ch. hastata; *1648* (**18c**) C. lasiophyllus var. utahensis; *2634* (**18**) C. lasiophyllus; *3129* (**13**) C. heterophyllus; *3767* (**10**) T. laciniatum; *3768* (**7**) T. sagittatum; *3769* (**3**) T. crispum; *3771* (**9**) T. flexuosum; *3772* (**10b**) T. laciniatum var milleflorum; *3775* (**4**) C. glaucus; *3776* (**8**) C. crassicaulis; *3777* (**5**) C. pilosus; *5522* (**14**) T. lilacinum; *5559* (**1a**) Stan. Wrightii var. tenella; *5655, 5684h, 5685* (**7**) C. major; *6015c* (**5**) T. ovalifolium; *6170* (**5**) C. pilosus; (**9**) C. Cooperi; (**8**) C. crassicaulis; (**4**) C. glaucus; (**18**) C. lasiophyllus; (**7**) C. major; (**5**) C. pilosus; (**1**) Strep. longirostris; (**3**) T. crispum; (**10**) T. laciniatum; (**10b**) T. laciniatum var. milleflorum; (**10a**) T. laciniatum var. streptanthoides; (**14a**) T. lilacinum var. subumbellatum; (**11**) T. rhomboideum.

Jones, W. W
(**14a**) T. lilacinum var. subumbellatum.

Kellogg, A. & Harford, W. G. W.
54 (**18a**) C. lasiophyllus var. inalienus; *55* (**18**) C. lasiophyllus.

Kelsey, F. D.
257 (**14a**) T. lilacinum var. subumbellatum.

Kennedy, P. B.
1003, 1975 (**10**) T. laciniatum; *1999, 2035* (**1**) Strep. longirostris; *3038* (**7**) C. major.

King, M. A.
(**18**) C. lasiophyllus; (**10**) C. simulans.

Leiberg, J. B.
172 (**10**) T. laciniatum; *396* (**9**) T. flexuosum; *455* (**4**) T. Howellii; *817* (**12**) T. integrifolium; *2039* (**9**) T. flexuosum.

Leidy, J.
(**14**) T. lilacinum.

Lemmon, J. G.
12, 24 (**3**) T. crispum; *40* (**10b**) T. laciniatum var. milleflorum; (**3**) T. crispum.

Leonard, F. E.
(**7**) T. sagittatum.

Letterman, G. W.
13 (**7a**) T. sagittatum var. crassicarpum.

Lunell, J.
(**10**) T. laciniatum; (**10a**) T. laciniatum var. streptanthoides.

Macbride, J. F.
88 (**5**) C. pilosus; *234, 796* (**10b**) T. laciniatum var. milleflorum; *883* (**5**) C. pilosus; *2569* (**14**) T. lilacinum.

Macbride, J. F. & Payson, E. B.
2982 (**7**) T. sagittatum; *3094* (**10b**) T. laciniatum var. milleflorum; *3360* (**14**) T. lilacinum.
Mann, C.
(**1**) Stan. Wrightii.
Meislahn, M.
36 (**1**) W. amplexifolia.
Metcalfe, O. B.
385 (**1**) Stan. Wrightii.
Michener & Bioletti, F. T.
(**16**) C. flavescens.
Mohr. C.
(**2**) W. sessilifolia.
Mulford, A. I.
(**8**) C. crassicaulis; (**10b**) T. laciniatum var. milleflorum; (**14**) T. lilacinum; (**7**) T. sagittatum.
Nash, G. V.
2544 (**2**) W. sessilifolia.
Nelson, A.
58 (**7a**) T. sagittatum var. crassicarpum; *574, 747* (**14**) T. lilacinum; *922* (**7a**) T. sagittatum var. crassicarpum; *1663* (**14**) T. lilacinum; *3013* (**7**) T. sagittatum; *3082* (**1**) Strep. longirostris; *4140* (**14**) T. lilacinum; *4545, 4673, 7164* (**7**) T. sagittatum; *7606* (**14**) T. lilacinum; (**14**)T. lilacinum.
Nelson, A. & Macbride, J. F.
1343 (**10**) T. laciniatum; *1346* (**7**) T. sagittatum; *1349* (**14**) T. lilacinum; *1380* (**14a**) T. lilacinum var. subumbellatum; *2085* (**7**) T. sagittatum.
Nelson, A. & Nelson, E.
5474 (**7a**) T. sagittatum var. crassicarpum; *6034* (**14a**) T. lilacinum var. subumbellatum; *6663* (**7a**) T. sagittatum var. crassicarpum.
Nevius, R. D.
(**1**) T. eucosum.
Oleson, O. M.
242 (**14a**) T. lilacinum var. subumbellatum.
Orcutt, C. R.
945 (**1**) Stan. Wrightii; *1024* (**18**) C. lasiophyllus; (**9**) C. Cooperi; (**18**) C. lasiophyllus.
Osterhout, G. E.
5755 (**1**) Stan. Wrightii; (**14**) T. lilacinum.
Palmer, E.
4 (**18**) C. lasiophyllus; *21* (**18c**) C. lasiophyllus var. utahensis; *22* (**10**) T. rhomboideum; *24* (**8a**) C. crassicaulis var. glaber; *25* (**5**) T. ovalifolium; *28* (**18c**) C. lasiophyllus var. utahensis; *225* (**13**) T. affine.
Parish, S. B.
1435 (**13**) T. affine; *1794* (**8**) T. stenopetalum; *2326* (**1**) C. amplexicaulis; *3034* (**7**) C. major; *3036* (**1**) C. amplexicaulis; *3777* (**7**) C. major; *3787* (**8**) T. stenopetalum; *10532* (**13**) T. affine; *11797* (**18c**) C. lasiophyllus var. utahensis; (**1**) C. amplexicaulis.
Parish, S. B. & W. F.
846 (**1**) C. amplexicaulis; *1485* (**13**) T. affine; *1492* (**7**) C. major; (**13**) C. heterophyllus.
Parry, C. C.
9 (**1**) Strep. longirostris; (**13**) C. heterophyllus; (**12**) C. Lemmonii; (**13**) T. affine; (**14a**) T. lilacinum var. subumbellatum.
Payson, E. B.
280, 301 (**1**) Strep. longirostris.
Payson, E. B. & Payson, L. B.
1728 (**10b**) T. laciniatum var. milleflorum.
Piper, C. V.
1473 (**10a**) T. laciniatum var. streptanthoides.
Pringle, C. G.
(**13**) C. heterophyllus; (**3**) C. inflatus.

Purpus, C. A.
5065 (**11**) C. Coulteri; *5956* (**5**) C. pilosus; *5974* (**4**) C. glaucus; *5992* (**8**) C. crassicaulis; *6231* (**1**) Stan. Wrightii.
Ramaley, F. & Robbins, W. W.
3627 (**14**) T. lilacinum.
Redfield, J. H.
418 (**1**) Stan. Wrightii.
Romer.
(**2**) W. sessilifolia.
Rose, J. N. & Fitch, W. R.
17515 (**1**) Stan. Wrightii.
Rusby, H. H.
26 (**1**) Stan. Wrightii.
Rydberg, P. A. & Carlton, E. C.
6926 (**14**) T. lilacinum.
Rydberg, P. A. & Garrett, A. O.
9429 (**11a**) T. rhomboideum var. gracilipes.
Sandberg, J. H. & Leiberg, J. B.
190 (**10**) T. laciniatum; *229* (**10a**) T. laciniatum var. streptanthoides.
Savage, T. E., Cameron, J. E. & Lenocker, F. E.
(**10**) T. laciniatum.
Setchell, W. A.
(**18**) C. lasiophyllus.
Sharp, S. S.
432 (**14**) T. lilacinum.
Shockley, W. H.
5 (**5**) C. pilosus; *19* (**4**) C. glaucus; *252* (**8**) C. crassicaulis.
Skehan, J.
42 (**1**) Stan. Wrightii.
Smith, C. P.
1529, 1640 (**7**) T. sagittatum; *2003* (**14**) T. lilacinum; *2121* (**7**) T. sagittatum.
Smith, J. D.
(**3**) W. cuneifolia.
Sonne, C. F.
337 (**3**) T. crispum; (**16**) C. flavescens; (**18a**) C. lasiophyllus var. inalienus; (**3**) T. crispum; (**10b**) T. laciniatum var. milleflorum.
Stokes, S. G.
(**8**) C. crassicaulis.
Suksdorf, W. N.
841 (**10**) T. laciniatum; *953* (**18**) C. lasiophyllus.
Summers, Mrs. R. W.
(**18a**) C. lasiophyllus var. inalienus.
Tidestrom, I.
(**18**) C. lasiophyllus.
Torrey, J.
14 (**3**) T. crispum.
Toumey, J. W.
(**1**) Stan. Wrightii.
Tracy, J. P.
599 (**18a**) C. lasiophyllus var. inalienus; *1500½, 1501, 1730* (**18**) C. lasiophyllus; *2075, 1780* (**18a**) C. lasiophyllus var. inalienus; *4907* (**18**) C. lasiophyllus.
Tracy, S. M.
6428 (**2**) W. sessilifolia.
Trask, B.
(**18**) C. lasiophyllus.
Trelease, W.
3991 (**10**) T. laciniatum; (**18**) C. lasiophyllus.
Turesson, G.
42 (**10b**) T. laciniatum var. milleflorum.

Vasey, G.
194 (**7a**) T. sagittatum var. crassicarpum; (**14**) T. lilacinum.
Walker, E. P.
369 (**11a**) T. rhomboideum var. gracilipes.
Walker, H. A.
570 (**18a**) C. lasiophyllus var. inalienus.
Ward, L. F.
177 (**8**) C. crassicaulis.
Webber, H. J.
20 (**1**) W. amplexifolia.
Wooton, E. O.
194 (**1**) Stan. Wrightii; (**1**) Stan. Wrightii.
Wright, C.
845 (**1**) Stan. Wrightii.
Wright, W. G.
(**1**) C. amplexicaulis.

Index to Species

New species, varieties, and combinations are printed in **bold face** type; synonyms, in *italics;* and previously published names, in ordinary type.

	Page
Arabis longirostris	310
Caulanthus	247, 283
amplexicaulis	285
anceps	308
californicus	299
Cooperi	293
Coulteri	296
crassicaulis	292
crassicaulis var. glaber	293
crassicaulis var. *major*	291
flavescens	301
glaber	293
glaucus	288
Hallii	290
hastatus	282
heterophyllus	298
inflatus	287
lasiophyllus	303
lasiophyllus var. inalienus	306
lasiophyllus var. rigidus	307
lasiophyllus var. utahensis	307
Lemmonii	297
major	291
pilosus	289
procerus	291, 302
senilis	292
simulans	295
stenocarpus	300
sulfureus	286
Chlorocrambe	245, 282
hastata	282
Cleome cuneifolia	313
Erysimum retrofractum	304
Euclisia amplexicaulis	285
Euklisia longirostris	310
Guillenia	283

	Page
Cooperi	293
flavescens	302
Hookeri	302
inaliena	306
lasiophylla	304
rigida	307
rostrata	310
Hesperidanthus	259
Heterothrix	259
Macropodium	261
laciniatum	272
Pachypodium	261
ciliatum	272
integrifolium	277, 279
laciniatum	272
sagittatum	267
Pleurophragma	241, 261
gracilipes	277
integrifolium	277, 279
platypodum	276
Sisymbrium	258
acutangulum	306
acuticarpum	306
deflexum	304, 307
deflexum var. *xerophilum*	304
erysimioides	258
lasiophyllum	304
reflexum	304
Stanfordia	283
californica	299
Stanleya	
amplexifolia	312
confertiflora	244
gracilis	313
Stanleyella	256, 315
Wrightii	315

Page

Wrightii var. **tenellum** ---------- 317
Streptanthella ----------255, 309
longirostris ---------- 310
Streptanthus ---------- 283
californicus ---------- 299
campestris ---------- 286
Coulteri ---------- 296
crassicaulis ---------- 292
flavescens ---------- 301
heterophyllus ---------- 296
Howellii ---------- 265
inflatus ---------- 287
longirostris ---------- 310
Parryi ---------- 297
procerus ---------- 301
sagittatus ---------- 267
Thelypodiopsis ---------- 242
aureum ---------- 244
elegans ---------- 243
Thelypodium ---------- 260
affine ---------- 278
ambiguum ---------- 243
amplifolium ---------- 267
brachycarpum ---------- 263
brachycarpum ---------- 264
Cooperi ---------- 293
crispum ---------- 264
deserti ---------- 294
eucosum ---------- 262
flavescens ---------- 301, 302
flexuosum ---------- 271
gracilipes ---------- 277
Greenei ---------- 302
Hookeri ---------- 302
Howellii ---------- 265
integrifolium ---------- 277
integrifolium -- 276, 277, 278, 279, 281
integrifolium var. *gracilipes* -- 277
laciniatum ---------- 272
laciniatum var. **milleflorum** ---- 274

Page

laciniatum var. **streptanthoides** 274
laciniatum ---------- 274
lasiophyllum ---------- 304, 307
lasiophyllum var. *inalienum* --- 306
lasiophyllum var. *rigidum* ---- 307
lasiophyllum forma *xerophilum* 304
Lemmoni ---------- 303
leptosepalum ---------- 272
lilacinum ---------- 279
lilacinum var. **subumbellatum** -- 281
macropetalum ---------- 268
milleflorum ---------- 274
neglectum ---------- 272, 304
Nuttallii ---------- 262, 267
ovalifolium ---------- 266
Palmeri ---------- 266
paniculatum ---------- 268
rhomboideum ---------- 276
rhomboideum var. **gracilipes** -- 277
rigidum ---------- 307
sagittatum ---------- 267
sagittatum var. **crassicarpum** -- 269
sagittatum ----------268, 269
simplex ---------- 265
stenopetalum ---------- 271
streptanthoides ---------- 274
torulosum ----------268, 269
utahense ---------- 307
vernale ---------- 267
Wrightii ---------- 315
Wrightii var. *tenellum* ---------- 317
Thelypodium ---------- 283
Turritis lasiophylla ---------- 303
Warea ----------256, 311
amplexifolia ---------- 312
amplexifolia ---------- 312
Carteri ---------- 314
cuneifolia ---------- 313
cuneifolia ---------- 314
sessilifolia ---------- 312

A NEW HYBRID NYMPHAEA

GEORGE H. PRING

Horticulturist to the Missouri Botanical Garden

During the past two seasons various experiments in breeding water-lilies have been undertaken at the Garden, especially with *Nymphaea* "Mrs. Edwards Whitaker" as a parent, with both interesting and disappointing results in the progeny.

The principal disappointment to the writer at first was the inability to obtain a "Whitaker" type with a viviparous leaf character, despite the fact of using viviparous parents, such as *N. daubeniana, N.* "Mrs. Woodrow Wilson" var. *gigantea,* and *N.* "Panama Pacific," reciprocal crosses being made in each case with *N.* "Mrs. Edwards Whitaker." This unusual leaf character present in the later hybrids has originated from the species *N. micrantha.* The desirable factor with the viviparous hybrids is the ease with which the type is perpetuated through the young plantlets which grow upon the parent leaves. Propagation is accomplished when thinning out the leaves during the summer, the young plants being easily cut from the center of the leaves. They are then potted and transferred to the greenhouse tanks for the next season's display. With the non-viviparous hybrids the parent plants must be dug from the ponds in October or prior to frost and placed in the greenhouse tanks until they die down, when they are cleaned to ascertain whether or not young basal tubers have developed. The large-flowered forms of *N.* "Mrs. Edwards Whitaker" always develop extremely large parent tubers during the summer which ordinarily last but one season, and in most instances they lack the small tubers necessary for the next season. To keep up a stock of this lily it is therefore necessary to grow plants in pots during the summer for tuber development.

× NYMPHAEA "MRS. G. H. PRING," PRING, N. HYB.

(*N. ovalifolia* ♀ × *N.* "Mrs. Edwards Whitaker" ♂)

Up to the present time the only pure white tropical day-blooming water-lily in cultivation has been the small-flowered *Nymphaea flavo-virens* (*gracilis*) native of Mexico. It has been used to advantage in breeding, being the parent of such popular hybrids as *N.* "Stella Gurney," "Mrs. C. W. Ward," and "William Stone,"

but when grown for floral display it is rather disappointing on account of the small size of the flowers. The writer therefore experimented with a view of obtaining a white lily comparable to the present-day horticultural forms. Stock of *N.* "Mrs. Edwards Whitaker" was selected as a desirable parent because its flowers frequently bleach to white with age and also because white forms resembling *N. ovalifolia* appear in the second generation.

During 1919 reciprocal crosses were made between *N.* "Mrs. Edwards Whitaker" and its parent *N. ovalifolia.* A number of seedlings were raised during the winter and planted in the ponds outside. *Nymphaea* "Mrs. Edwards Whitaker" ♀ × *ovalifolia* ♂ resulted in forms of the Whitaker type, while the reciprocal cross, *N. ovalifolia* ♂ × "Whitaker" ♂ , showed *ovalifolia* or the white form as a dominant factor. One pure albino form possessing the large Whitaker-shaped flowers and leaf characters was selected as the desired type. It was carefully self-pollinated during the summer of 1920, the offspring producing albino flowers. In 1921 the finest flowers were again selected and self-pollinated, the seedlings again producing pure white flowers but with an improvement both in number and size of petals. By careful selection and self-pollination during the past season all pink and blue shades which dominated the parent flowers have been eliminated. The new hybrid produces plenty of fertile seeds, a factor not evident in most present-day hybrids.

Description.—Flowers white, 8–10 inches across, opening for 5–6 successive days from 7 A. M. to 6 P. M. during August, 3–5 opening at one time, extremely fragrant; bud narrowly ovate-acuminate, light green sparsely striped with irregular minute dark purple lines; peduncle terete, rising 1 foot above the water, in cross-section showing 7 main air-canals circled by 15–16 smaller ones; sepals 4-wedged, ovate-triangular, somewhat hooded at the apex, thick, fleshy in texture, outer surface light green, sparsely striped with irregular dark purple lines, inner surface white, greenish white at the base, showing 10–12 nerves; petals white, comprising 3 whorls, the outermost lanceolate, obtuse, 4 inches long, ¾–1 inch wide, outer surface showing light green at the thickened base, 6–8-nerved, inner whorls pure white, innermost whorl smaller; stamens 120–130, canary-yellow, outer whorls white at the apex, 2 inches long, with appendages ovate-oblong at the base, linear above, inner whorls becoming shorter and narrower toward the innermost, which is linear; carpels 28–

30, with styles oblong, obtuse, introrse, yellow; fruit globose, well filled with fertile seeds; developed leaves narrowly peltate, ovate to suborbicular, 16 inches long by 14 inches wide, with sinuate margins becoming deeper at the base, almost entire at the apex; sinuses overlapping, terminating into acuminate lobes, green on the upper surface, faintly spotted with reddish brown, fading away as the leaves develop, the under surface light green flushed with pink; petioles light brown, measuring 6–8 feet when fully developed.

Var. marmorata.—Flowers same as type; leaves light green, irregularly blotched with reddish brown upon the upper surface. This marmoration is transfused from *Nymphaea* "Mrs. Edwards Whitaker."

Explanation of Plate

PLATE 20

Showing parentage of *Nymphaea* "Mrs. G. H. Pring."

Left, *N.* "Mrs. Edwards Whitaker" ♂, lavender-blue.
Right, *N. ovalifolia* ♀, white, blue-tipped.
Center, *N.* "Mrs. G. H. Pring," albino.

PRING—A NEW HYBRID NYMPHAEA

Explanation of Plate

PLATE 21

Showing difference between the white *Nymphaea gracilis*, native of Mexico, and new white hybrid, *N.* "Mrs. G. H. Pring."

PRING A NEW HYBRID NYMPHAEA

Explanation of Plate

PLATE 22

Nymphaea "Mrs. G. H. Pring," growing in the ponds of the Missouri Botanical Garden, St. Louis. Photograph taken August 1, 1922.

PRING—A NEW HYBRID NYMPHAEA

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A BACTERIAL DISEASE OF FOXTAIL (CHAETOCHLOA LUTESCENS)[1]

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Introduction

In a brief note published in March, 1919, the writer called attention to a disease of foxtail common in Arkansas. It was pointed out that the pathogen, a whitish bacillus, was capable of attacking a number of grasses, including most of the common cereals. Since then an intensive study has been made of this disease, with the object of establishing its symptoms and etiology, and in the pursuit of this investigation facts were evolved which clearly showed the necessity of using certain methods in the study of plant pathogens which are not ordinarily in vogue among plant pathologists.

Bacterial Diseases of Gramineae in General

Since the studies here presented indicate that the disease producer has not been previously described it seems desirable, for comparison, to review briefly the bacterial diseases of the *Gramineae.* Smith (I, '20, p. 7)[2] has recently given a list of plant genera which are known to be attacked by one or more bacterial species. In this is included the following grass genera: *Hordeum, Dactylis, Bromus, Zea, Setaria, Andropogon, Avena, Saccharum, Secale, Triticum, Phleum, Poa,* and *Agropyron.* These 13 genera,

[1]Submitted for publication May, 1922.

[2]The bibliography is divided into two parts, the first part dealing with references to bacterial diseases of grasses, designated I, and the second part dealing with morphological and physiological references, designated II.

he also states (p. 4), are attacked by 14 different disease producers. Not having mentioned these by name or by citation to literature, it becomes rather difficult to ascertain the organisms which he included. It is quite possible that 1 or more of these 14 have not as yet appeared in print and are known only to Dr. Smith. Of the host genera which he lists, no reference has been found to a bacterial disease of *Bromus*, and aside from Manns' (I, '09) brief reference to a disease on the blue grasses which, according to the author, appeared to be the same disease as that on oats, no other literature dealing with a bacterial disease of *Poa* has been found. Concerning a bacterial disease of *Phleum* but little more information is available. Manns refers to a bacterial disease of timothy in the same sentence, cited above, in which reference is also made to a disease of *Poa*. In addition to this reference, a blade blight of timothy "apparently bacterial" was reported in Ohio during 1918 and 1919 by the Plant Disease Survey (I, '19, p. 157, and '20, p. 76), and Jones, Johnson, and Reddy (I, '17) mention a bacterial disease of *Phleum pratense*.

Of the bacterial diseases of grasses which are well known or supposedly well known it will perhaps be desirable to characterize briefly each one, noting the similarities and the differences as compared with the foxtail organism. A chronological sequence will be followed.

One of the very first investigators of bacteria in relation to plant disease and perhaps the first to study carefully a bacterial disease of a grass was Prillieux. His account of a rose-red disease of wheat kernels (I, '78) is well known. He made no pure culture studies, so that it is not possible to identify definitely the organism he described. Gentner (I, '20) has recently published an account of a bacterial disease of barley in which he states that the pathogen when inoculated in pure culture into sterilized kernels of barley, wheat, and corn produces a reddish discoloration. He believes that the organism with which he worked, a rod-shaped, red-pigment producer, named by him *Bacillus cerealium*, is the same as Prillieux's organism and that the *Micrococcus* which Prillieux found associated with discolored wheat kernels represents the spore stage of *B. cerealium*. The fact that this organism produces a red pigment on various media and is a spore producer, an anomaly among plant pathogens, would immediately distinguish it from the foxtail organism.

In 1887 Burrill described a disease of broom-corn and sorghum which he attributed to bacteria. Two years later, Kellerman and Swingle (I, '89), under the name of "sorghum blight," published an account of a disease which they considered the same as Burrill's; they also accepted and seemingly substantiated his work on the pathogenicity of the organism which he had named *Bacillus Sorghi.* Several other investigators before and after Burrill's time have worked on red spots of sorghum, but to this day we have little exact information on the disease. Thus Palmerie and Comes in 1883 decided that red discolorations of sorghum were due to yeasts and bacteria; Radais in 1899 concluded that sorghum blight was due to yeasts; and Busse (I, '05), in a rather extensive paper, showed that various causes can produce reddening of sorghum. Concerning any bacterial disease of sorghum, Busse concluded that there was no specific bacterial pathogen involved, that the bacteria which have been found within the tissues were merely facultative parasites which entered by means of injuries induced by insects and other agents and that *Bacillus Sorghi* was an organism of this sort. The writer does not intend to go extensively into this disease, or rather group of diseases, at this time; suffice it to say that as far as the written descriptions of *B. Sorghi* are concerned the organism cannot be identified. While apparently accepting Burrill's organism in an early publication (Smith and Hedges, I, '05) Smith handles it with great caution in other publications (I, '05, p. 66, p. 92, pl. 20 [opposite p. 150]; '11, p. 62 and 63), not definitely rejecting it but substituting another name, *Bacterium Andropogoni.* Smith's complete account of *B. Andropogoni* follows: "It is non-sporiferous, polar-flagellate (1–3), and white on culture media, forming small circular colonies on agar-poured plates. It is aerobic, non-liquefying, non-reducing (nitrates)." Manifestly this preliminary description also is so incomplete that it is impossible to make any adequate comparison with an unidentified organism. We may note, however, that the foxtail organism possesses similar characters with the exception that it has but a single polar flagellum and is a marked nitrate reducer. The writer's preliminary studies on a bacterial disease of sorghum present in Arkansas indicates that the pathogen there concerned is different from the foxtail organism.

Following the description of a bacterial disease of sorghum Burrill (I, '89) described a bacterial disease of field corn. For

the present I may merely refer to my descriptions of a bacterial disease of field corn (I, '19[a], '21) and to note, as will be fully discussed in another publication, that Burrill's organism is either not identifiable or is not related to disease production. The pathogen is quite unlike the foxtail organism.

In 1893 Cobb described a bacterial disease of sugar cane. The disease is so thoroughly described by Smith (I, '14, pp. 3–71) that there is no necessity for discussion of it here. We may note, however, that *Pseudomonas vascularum,* a yellow rod, is typically a vascular disease producer. These characters alone are sufficient to distinguish it from the foxtail organism.

A bacterial disease of sweet corn was first described by Stewart (I, '97); this, like the sugar cane disease, is also a vascular parasite, is yellow in color, and according to recent investigations (McCulloch I, '18), is non-motile. All these features, as well as others, indicate that it is quite distinct from the foxtail pathogen.

Another non-motile, yellow parasite is *Aplanobacter Rathayi.* It was first described by Rathay in 1899 as attacking orchard grass near Vienna. According to Smith (I, '14, p. 155), who gives a good account of this disease, it is also present in Denmark. Descriptions indicate that this also is distinct from the motile, white, foxtail organism.

In 1901 Guffroy described knots on rhizomes of *Arrhenatherum elatius* which he decided were brought about by bacteria; he named the organism *Bacterium moniliformans.* The original article has not been seen by the writer, but according to Sorauer (I, '08, p. 30) Guffroy has presented no proof for his conclusions.

Voglino (I, '05, pp. 43–44) described a bacterial disease of rice, present in Italy. The large size of the organism, 2.5–3.5 × 3.8–4.0 μ, should readily distinguish it from all other organisms attacking grasses.

Manns (I, '09) published an extensive account of a bacterial disease of oats, although Galloway and Southworth as early as 1890 and Russell in 1892 briefly described a bacterial disease of the same host. It may be noted that Manns' conclusions concerning the cause of the disease have been questioned, and more recently Miss Elliott (I, '20) has given a detailed account of a halo-blight of oats. Concerning the disease which Manns described, she says (p. 167); "His colored figures as well as most of his text indicate an entirely different disease, but his Plate

XIII shows that this halo-disease formed at least a part of the phenomenon under consideration." She states further (p. 168), that "Manns' descriptions of individual lesions are so meager and his descriptions of general signs so inclusive as to lead to grave doubt about his having worked with a single bacterial disease." This statement is somewhat different from the one made by Miss Elliott in a previous publication (I, '18). In this she says, "The characteristic halo lesions of this disease have been definitely observed in Wisconsin during each of the past five years and are similar to those figured by Manns (Pl. XIII) in his Ohio bulletin of 1909. The results of the writer's work on halo blight of oats agree with those reported by Jones, Johnson, and Reddy* ('17) in that typical halo lesions are readily produced by a white bacterial pathogen alone." In view of the facts that Manns had included a number of grasses as hosts and that Jones and his associates had accepted *Pseudomonas Avenae* as the pathogen I made the following statement in a preliminary note on the foxtail disease: "The effect on oats is not unlike the halo blight recently described by Miss Elliott and it is likely that the organism under discussion is the same as Manns' *Pseudomonas Avenae.* However the identity of the organism is still in doubt and the work is being continued."

The writer is now in a position to say that Manns' description of *P. Avenae* is quite at variance with the account of the foxtail organism which will be presented later. It must be borne in mind, however, that bacteriological methods and descriptions in 1909 were not as well developed as they have become in more recent years, and when, for example, endospores are recorded in 1909 it must not be assumed that this is an established fact; the same thing may be said for a large number of cultural reactions. However, while the foxtail organism may be present in Ohio, Manns' description as well as Miss Elliott's, even when interpreted very broadly, clearly indicates a difference in the organism. A comparison of group numbers, using the 1907 chart of the American Bacteriological Society, shows at a glance the marked difference between the foxtail organism and *P. Avenae.* Manns' group number (I, '09, p. 133) is 111.2223032, while the group number of the foxtail organism is 212.3333013. Among other differences it may be noted that the foxtail organism does not liquefy gelatin, produces no acid, even in the presence of car-

*These writers considered Manns' *Pseudomonas Avenae* as the causal organism.

bohydrates, and produces strong diastatic action, characters quite different from those described for *P. Avenae.*

Miss Elliott was kind enough to send the writer a culture of *Bacterium coronafaciens*, the causal agent of the halo-blight of oats, and comparison of this organism with the foxtail pathogen shows distinct differences. As Miss Elliott states, *B. coronafaciens* usually occurs in chains and produces a brownish color on nutrient agar; these characters serve to distinguish it immediately from the foxtail organism, which usually occurs singly or in pairs and produces no brown color on nutrient agar. There are also a number of other morphological and physiological differences which can be readily ascertained by comparing the description of the foxtail organism given below with the one given by Miss Elliott (I, '20). Before closing the reference to bacterial diseases of oats the writer wishes to call attention to a pathogen isolated by him from reddish spots of oats, an organism which when inoculated in pure culture, produced the same kind of spots (no halos are produced). This organism, a white, monotrichous rod, is a strong gelatin liquefier and does not attack foxtail. It apparently is not *Bacterium coronafaciens.*

A bacterial disease of western wheat-grass was described by O'Gara in 1915 (I, '15, '15[a]). The pathogen, *Aplanobacter Agropyri,* is yellow and non-motile and thus quite different from the foxtail organism.

In 1916 Jones, Johnson, and Reddy briefly described a bacterial blight of barley and certain other cereals. This was followed by a more complete description in 1917. In this, also, a yellow organism, *Bacterium translucens,* is involved. Besides barley, these writers have found that wheat, spelt, rye, timothy, and oats are attacked by similar bacterial diseases, but that the barley organism, *B. translucens,* does not attack the other grasses listed above. Attention has already been called to a bacterial disease of barley found in Germany by Gentner (I, '20). While proof has been given that *Bacillus cerealium* may produce disintegration of seed, it seems to me that more work would be necessary before any conclusion could be drawn regarding the production of brown spots on various organs of the barley plant. As indicated previously the organism differs greatly from the foxtail pathogen.

A new disease of wheat, now well known as black chaff, was first described by Smith in 1917. The pathogen is closely related to the one causing barley blight and has been named by Smith,

Jones, and Reddy (I, '19) *Bacterium translucens* var. *undulosum*. This organism goes as readily to barley as the barley organism itself, while the barley organism hardly attacks wheat. It also is a yellow pathogen.

Another bacterial disease of wheat was found in India by Hutchinson and first described in 1917. The descriptions indicate that the disease is quite similar to the one described by O'Gara (I, '15, '15[a]) on western wheat-grass. There is a marked distortion of the heads and the spikelets are covered by a yellow slime. The pathogenicity of the organism, *Pseudomonas Tritici* Hutch., has not as yet been definitely established. The symptoms, particularly the yellow slime, would indicate that it is quite different from the foxtail disease.

For convenience a third bacterial disease of wheat, the basal glumerot, may be considered next. It was discussed by Miss McCulloch in 1920, and the pathogen, *Bacterium atrofaciens,* described as a greenish pigment producer, is quite distinct from the foxtail organism.

In closing the historical resumé of bacterial diseases of grasses it should be noted that no attempt has been made to include all references, but rather those of significance in relation to the disease producer here investigated. The 14 grass genera listed by Smith (I, '20) have been included and besides these reference has been made to a bacterial disease of *Arrhenatherum* and of *Oryza*. In addition special attention may be called to the very brief notice of a bacterial disease of millet (listed under *Panicum* sp.[1] but perhaps intended to be *Chaetochloa* (*Setaria*) sp.) in a supplement bulletin of the Plant Disease Survey (I, '19, p. 157). The note reads: "Blight, apparently of bacterial cause, was noticed on three varieties of millet in Minnesota about August 17." This reference is of particular interest, since millet, *Chaetochloa italica* (*Setaria italica*), is closely related to foxtail, *Chaetochloa lutescens* (*Setaria glauca*) and in the seedling stage is as readily attacked by the foxtail organism as foxtail itself. Various other references have been found to bacterial diseases of grasses, including those which produced spots on rye and on corn, but these are so brief as to be of no special significance for present purposes.

[1]There are a number of different grasses going under the name of millet, but the names foxtail, millet, or Italian millet are applied to *Chaetochloa italica,* while proso or broom-corn millet are applied to *Panicum miliaceum*. The latter is but sparingly grown in this country. (See Hitchcock, U. S. Dept. Agr., Bur. Pl. Ind. Bul. 772. 1920.)

General Description of the Disease

The symptoms of the disease vary somewhat with host and considerably with conditions under which infection takes place. The pathogen grows best at relatively high temperatures, so that other conditions being favorable, at a temperature of around 90° F. the first signs of infection will occur in 24 to 48 hours. Under very moist conditions the spots appear water-soaked at first and as the atmosphere becomes dry they appear as light brown or grayish brown spots or streaks. On foxtail and on *Chaetochloa geniculata* these spots may be bordered by a distinct brown or reddish brown area (see pl. 23, fig. 1). Under favorable conditions of infection attacked areas often appear grayish green, withered, looking as if scalded, and surrounded by a somewhat indefinite yellowish halo. The spots on foxtail as they occur naturally in the field, in a dry atmosphere, are usually of two types, (1), small, reddish brown, round or oval-shaped areas enclosing lighter brown centers, and (2), light or dark brown or blackish streaks, usually starting at the tip of the leaf and often including a large part of leaf area. The spots may appear on any part above ground, including leaf-sheath as well as blade, rachis, and glume. Under natural conditions spots are more often to be observed on the leaf blades.

On oats the spots vary from light yellow, somewhat indefinite areas to grayish green, markedly withered areas. Often there are marked tinges of red[1] in attacked areas, particularly when a number of infections have coalesced. Attacks may occur on seedlings or on plants that are in head. Numerous artificial inoculations have been made on various varieties of oat seedlings, and under favorable conditions of infection not a single oat plant out of a large number inoculated would remain alive 4 days after inoculation (see pl. 26, fig. 1). It is of course evident that a seedling with a limited surface is much more readily killed than a larger plant.

Attacks on wheat, rye, barley, and corn do not vary considerably from that on oats. There is usually very little red discoloration, the spots vary in size and shape, and the predominant discolorations are grayish green, light yellow, or brownish.

[1]The writer is satisfied that various agents can cause reddening of oat leaves. Under certain conditions of light and temperature a mere sharp crease in an oat blade may produce a reddening in the part above the crease. It is well known that the production of anthocyans may take place at low temperatures and when the transfer of foods is cut off, resulting in an accumulation of sugars. Attacks by aphids often appear as yellow or red discolorations.

withered areas. On barley and on corn very light yellow or whitish streaks are not uncommon. Barley seedlings, as well as oats, succumb very readily (see pl. 26, fig. 2).

On millet the attack is usually in the form of grayish green, withered areas, occasionally with brown tinges. On various varieties of sorghum the spots are often grayish green bordered by a red band or merely a small red, irregular spot; reddening, it may be noted, being a much more general character of various sorghum diseases.

There are two diseases of foxtail which are of common occurrence in Arkansas as well as in other states, notably Delaware, Missouri, New York, and Pennsylvania, which may be mistaken for the bacterial disease. One of these is caused by *Cercospora Setariae* Atk. and the other is a *Piricularia* spot. The *Cercospora* attack is usually in the form of elongated dark brown streaks which usually exhibit the spore groups and thus are easily identified, while the *Piricularia* spot is usually roundish, light brown in color with a darker brown edge. These *Piricularia* spots may readily be confused with the bacterial spot because of their close resemblance and because the spores are often difficult to find. Microscopic examination will, however, usually bring out the difference. The bacterial spots are full of bacteria which in a water mount with slight pressure will stream out of the tissues in the form of dense, grayish white clouds. They may also be detected within the cells. Rarely are bacterial spots contaminated by fungi.

INTERNAL APPEARANCE AND PATHS OF INFECTION

Sections of diseased leaves show the bacteria present in great numbers within the cells and in the intercellular spaces (see pl. 27, fig. 1). The parenchyma is apparently the only part attacked, since no bacteria have been observed within the bundles. The attacked cells lose their turgidity, suffer partial or complete collapse, are more or less disintegrated, and variously discolored. Externally the collapse of cells is indicated by a shrinking and withering and finally by splits or breaks in the diseased parts. Ordinarily there is no oozing outward of bacteria, but under very moist conditions and where rifts have occurred in the tissues the bacteria are present in great numbers in the drops hanging to the rifts. This undoubtedly leads to the dissemination of the pathogen by rain and by winds. (Spreading by insects is also to be expected.)

Artificial inoculations clearly indicate that the pathogen enters by means of the natural openings, the stomata and the water-pores. Material fixed in chrom-acetic acid, imbedded in paraffin, sectioned, and stained with carbol-fuchsin has shown substomatal cavities full of bacteria, which in later stages of infection are surrounded by cells and intercellular spaces which are also full of bacteria (pl. 27, fig. 1). Regarding infection through water-pores it was noted that under certain conditions in the greenhouse, which included an extreme dryness of the atmosphere, resulting in an incipient wilting accompanied by a closing of the stomata, the few infections obtained occurred at the tips of the leaves, indicating entrance by means of the apical hydathode. This is of interest since it indicates that under natural conditions when stomata are closed, as at night, infection may take place through the water-pores.

HOSTS AND EXTENT OF INJURY

Thus far, foxtail is the only grass that has been found infected under natural conditions. This statement may not be of much significance, as the time spent in looking for the disease on other hosts was, by force of circumstance, very limited. The ease with which artificial infections are obtained on a number of wild and cultivated grasses indicates that the pathogen may be looked for on all the common cereals, particularly in the southern states. The following species representing 5 different tribes are susceptible, as proved by artificial inoculations: *Avena sativa, Chaetochloa geniculata, Chaetochloa italica, Chaetochloa lutescens, Holcus Sorghum* (*Andropogon Sorghum*), *Holcus Sorghum sudanensis, Hordeum vulgare, Secale cereale, Triticum sativum,* and *Zea Mays.*

A sufficient number of artificial inoculations and of reisolations have not been conducted with red top (*Agrostis palustris*) and with goose-grass (*Eleusine indica*) to warrant any definite statement, but preliminary tests would seem to show that these also are susceptible.

Artificial inoculations have given negative results with the following: *Poa pratensis, Syntherisma sanguinalis, Chaetochloa viridis, Festuca elatior, Oryza sativa,* and *Phleum pratense.*

The disease on foxtail has now been observed in northwest Arkansas for four successive seasons. Specimens have also been obtained from other portions of the state, indicating that the

disease is widespread throughout Arkansas. No effort has so far been made to locate the disease in other states, so that little is known concerning its distribution. It should be looked for particularly in the warmer sections of the country, since physiological studies indicate that the organism grows best at relatively high temperatures. Field infections on foxtail are at times severe, especially during warm, moist weather. Under such conditions it is not uncommon to find individual plants with almost every leaf-blade killed and with only the rachis and head showing a normal, green color. Lower leaves in particular are to be found diseased (indicating infections by spattering of rain drops). However, considering the extent of injury as observed over a period of several years there is no reason for viewing this disease with alarm. On one particular field where it has been under close observation for more than three years, the disease has occurred on 4 successive crops of foxtail without any apparent diminution in the number of volunteer plants that sprang up. Every year this field had been plowed, cultivated, and used for growing tomatoes and other crops, and by late summer, unless considerable hoeing were done, foxtail would "take" the field. In this connection it is worth while calling attention to the distribution and growing season of the host. Yellow foxtail is common in cultivated soil in the eastern United States (it is also very common in the Mississippi region) according to Hitchcock (U. S. Dept. Agr. Bull. 772, p. 243) and is "often sufficiently abundant to furnish considerable forage." It usually does not appear before midsummer and comes into full development by late August or early September. Thus we see a high, midsummer temperature favoring host development as well as that of parasite.

SUSCEPTIBLE VARIETIES OF COMMON CEREALS

The following varieties of common cereals[1] have been found susceptible in artificial infection experiments by methods which will be explained below. For each variety listed one or more pots each containing numerous plants were inoculated. When infections were few or uncertain other pots of the same variety were tried. Uninoculated plants served as checks. Because of rapidity of growth as well as ease of handling, seedlings 6–12

[1]The writer wishes to express his indebtedness to the Agricultural Experiment Station of the University of Arkansas and in particular to Professor W. H. Sachs for supplying most of the seed of the varieties listed. The varieties are for a large part those that are adaptable to Arkansas conditions.

inches high were largely used. (Numerous inoculation experiments show that maturer plants may be also infected.)

Wheat: Alabama Blue Stem, Coker's Blue Stem, Black Hulled, Fulcaster, Fultz, Georgia Red, Gladden, Golden Chaff, Gypsy, Harvester King, Hastings, Jones' Climax, Leap's Prolific, Lebanon, Marvelous, Medium Mediterranean, Michigan Wonder, Poole, Portage, Purple Straw, Red May, Red Wonder, Stover's Miracle, Turkey, Nebraska No. 6, and Turkish Amber.

No infections were obtained on Bartt, Beechwood Hybrid, Longberry, and Red Rock, but it should be noted that experiments would have to be repeated with these varieties before any deductions were made, since the temperature prevailing in the greenhouse at the time inoculations were conducted was considerably below the optimum for infection.

Oats: Appler, Ferguson, Virginia Turf, Wilson, Winter Gray, and Winter Turf.

Rye: Abruzzi, Rosen, Station, Texas Winter, and Winter Minnesota. Infections on Ivanhoff No. 34 not obtained.

Barley: Mancheuri, Oderbrucker, and Wisconsin Pedigree No. 6.

Corn: Arlington Prolific, Biggs' Seven Ear, Calhoun Red Cob, Chisholm, Coker's Ellis, Coker's Marlboro, Coker's Prolific, Coker's Williamson, Eureka, Experiment Station Yellow, Hickory King, Jarvis' Improved, Laguna Mexican June, McFarland, Mosby's Prolific, Sentell's White Dent, Singleton's Strawberry, Stewart's Yellow Dent, Surecropper, Thibault's Mexican June, Weekby's Improved, Whattey's Prolific, and White Wonder.

Varieties of corn upon which no infections were obtained are Brazos White Corn, Coker's Garric, Ewing's Mosby, Paymaster, Silvermine, and Southern Beauty. Time has not permitted any adequate study which would definitely show whether or not these are resistant.

Sorghum: Black Amber, Darco Non-saccharine, Honey, Red Amber, and Sugar Drip.

The following sorghum varieties yielded no infections: Broom Corn, Silvertop, Shrock Kafir, Sumac, and Sunrise Kafir. Here also conditions for infection were not the best.

SUMMARY OF THE WORK ON VARIETAL SUSCEPTIBILITY

The following points may be emphasized: first, that a comparatively large number of varieties of different cereals are susceptible; second, that the degree of susceptibility has not been

clearly worked out; third, that certain cereals, like oats, barley, and rye, seem to show greater susceptibility, and conversely, that others, like corn and sorghum, are not as susceptible. The infection experiments here reported were done entirely in the greenhouse, and at times factors influencing infection, such as temperature, were difficult to control, so that conditions for infection were not uniform. The degree of susceptibility was measured by the number and size of the spots produced.

Isolation and Inoculation Experiments

The organism was not difficult to isolate, and when once its identity was established and the peculiar behavior of producing a colorless halo surrounded by a white precipitate on certain culture media was recognized, it was easy to detect it on a poured plate, even in the presence of various other *Schizomycetes*. During the 4 years in which this disease has been studied, the pathogen has been isolated many times from natural infections and from artificial infections on various hosts, using the ordinary method of surface sterilization with 1-1000 mercuric chloride solutions for about 2 minutes, washing in several changes of sterile water, macerating aseptically either in sterile water or in beef bouillon, diluting variously by successive transfers into sterile water blanks, and finally by making poured plates containing small amounts of the dilution culture in nutrient agar. When proper precautions are taken, such as a thorough cleansing of hands, of clothing, and of the chamber in which the work is conducted it is common to get a series of plates in which the pathogen only is present.

Since the organism is very sensitive to alcohol, as will be shown later, attempts at surface sterilization with alcohol-mercuric chloride solution are apt to yield no colonies, although the writer has been able to obtain isolations in this way by a very rapid transfer of the diseased material from the alcoholic solution to the straight mercuric chloride solution.

In inoculation experiments the organism was at first smeared on the leaves by means of a sterilized platinum loop and in all later work was applied as a spray. The first method has the advantage of enabling one to locate definitely the point of inoculation in relation to the point of infection, but it is rather tedious when any number of inoculations are to be attempted. Either agar or broth cultures (the age of the cultures, within limits,

not being very important for this organism) were diluted with sterile water before the spray was applied. (In smear inoculations the plants were first sprayed with sterile water.) The spray was obtained by using atomizers or blowers commonly used by artists in "fixing" drawings. These work very rapidly and effectively, producing a fine mist with little effort.[1] The organism having been applied, the plants were then covered with bell jars to prevent drying out. The bell jars were ensconced with paper in order to cut down direct sunlight. The jars were left over the plants for 1 or 2 days, depending on how high the temperature happened to be. It may be worth recording that the difficulty experienced in obtaining infections in the experimental greenhouses of the Missouri Botanical Garden, although no such difficulty had been experienced at Fayetteville, Ark., was overcome by proper aëration. The greenhouse benches at the Garden are of concrete. When inoculated pots of plants were placed on soil which filled these benches, and the bell jars which covered the plants made close contact with the soil, infections were rare, no matter what the temperature and humidity happened to be. But by raising the jars from the soil on small blocks of wood the plants were still kept moist and at the same time had access to air. In this way infections were readily obtainable, other conditions being proper.

RELATION OF TEMPERATURE TO INFECTION

It has already been indicated that temperature plays an important role in infection. The reproduction of thermographs of artificial inoculations on Winter Turf oats carried out as previously described, illustrates this point (fig. 1).

The pot of plants subjected to the inoculation temperatures shown in the lower graph developed no infections, while that of the upper developed quite a few. It will be noted that where no infections were obtained the temperature over a large part of the 48-hour period was below 70° F. (21° C.), and particularly during the first 24-hour period the temperature was below 70° F. for 18 hours. The atmosphere was saturated and the leaves were covered with water films in both cases. It was found difficult to keep the incubator at an even temperature, so that no data are available which will show the relationship of infection to a definite temperature. Nevertheless, the graphs give some in-

[1]Dr. J. A. Elliott first suggested these blowers to me. They are cheap, easily sterilized, take up little space and do not plug readily.

dication on this point and when one considers the difference between night and day temperatures often encountered in the field the data shown are perhaps more indicative of infection to be expected under natural conditions than any experiment would show in which the temperature is kept at one level during the entire incubation period. Roughly then, it may be said that tem-

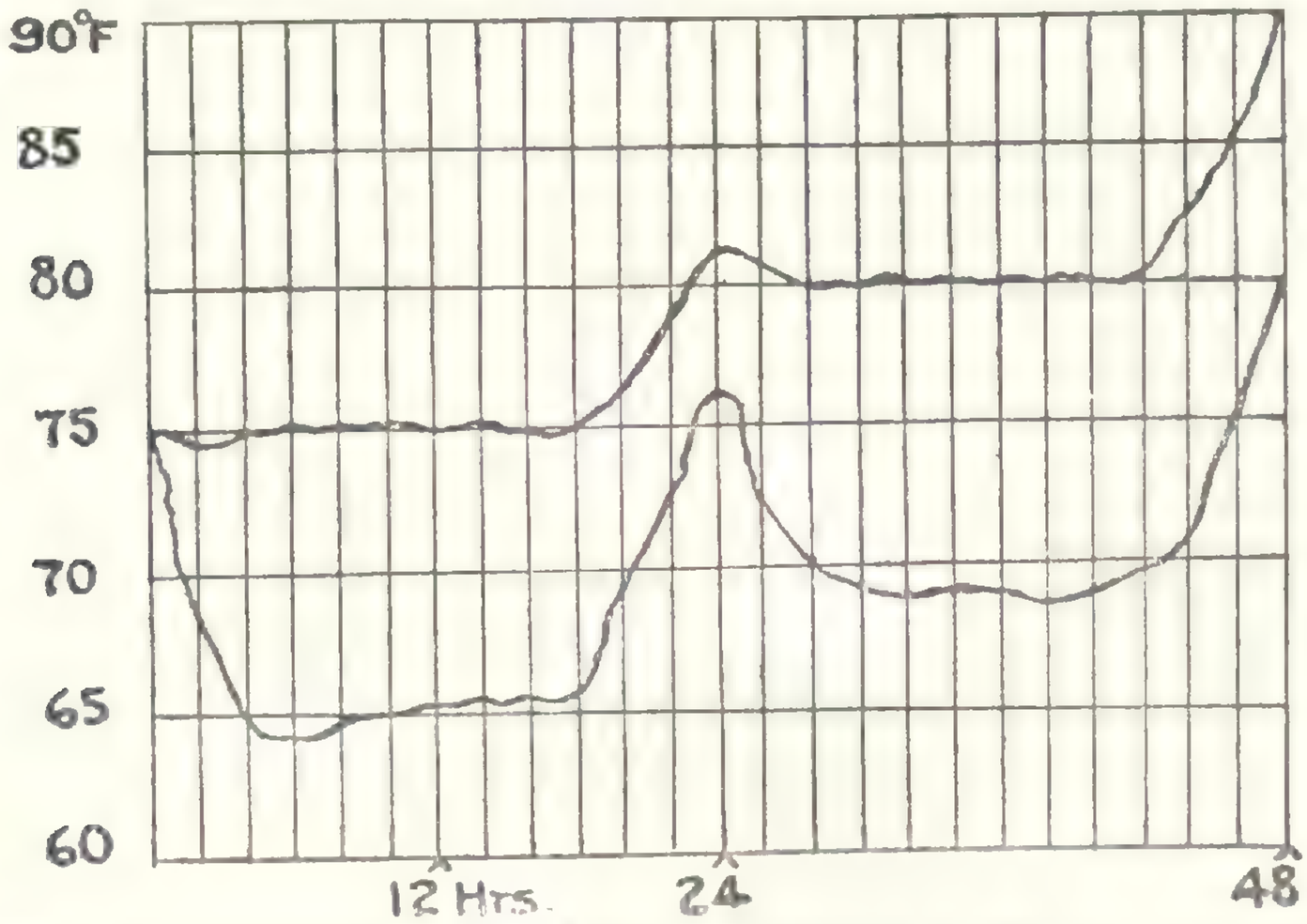

Fig. 1. Thermographs of artificial inoculations on Winter Turf oats.

peratures, during the infection and incubation periods, below 70° F. prevent infection, while temperatures above 75° F. are conducive to infection. It may be added that numerous artificial infection experiments show that heaviest infections occur at temperatures between 85 and 95° F. (29 and 35° C.). This is to be expected since growth in artificial culture media is best at these temperatures, as will be shown later.

THE ORGANISM

Morphology.—The organism is an actively motile, medium-sized rod. Whether obtained directly from the host tissue or whether grown on artificial media of various kinds no marked differences in morphology have been observed. It is rather slender (pl. 27, fig. 2) with rounded ends, and measures 0.5–0.8× 1.5–2.0 μ, 0.6×1.8 μ being very common measurements. Very rarely is it observed other than singly or in pairs, although occasionally a short chain of 4 or 6 organisms is to be seen. Its motion, which is very rapid in warm water, is due to a single, polar flagellum which varies somewhat in length but is commonly 3 to 5

times the length of the organism. Van Ermengem's stain brings out the flagella, but unfortunately it does not stain the body of the organism properly (pl. 27, fig. 3). Pitfield's stain as well as Shunk's (II, '20) modification of Loeffler's stain, has also shown but one polar flagellum. The latter stain, in particular, after the mordant has been seasoned for several weeks, forms an excellent stain for this organism, the disadvantage being that the blue color imparted by the methylene blue is difficult to photograph by ordinary methods.

The organism possesses capsules, as definitely shown by using Huntoon's (II, '17) method, "nutrose" being used as the diluent and Ziehl's carbol fuchsin added in addition to the stain recommended by Huntoon. This method, in contrast to Ribbert's or Welch's, is much more satisfactory in bringing out the capsule on this organism. Young and old cultures of the organism on nutrient agar slants and in bouillon were used, and capsules were observed in every case. No zoogloea or pseudozoogloea were formed, although in old cultures of beef-bouillon and particularly in bouillon containing various sugars, a dense precipitate settled, which on agitation rose in whorls and was broken up with difficulty.

The organism has not been found to produce spores. Cultures at various ages and on various media were examined. Anjesky's spore-staining method, recommended by Giltner ('Laboratory Manual,' 1921 edition) was used. It is not acid fast. A bouillon culture 3 days old stained with Ziehl's carbol-fuchsin and then treated with 20 per cent sulphuric acid for a moment, showed no color. When counterstained with aqueous methylene blue the organism appeared deep blue with no trace of red. It was Gram negative. A 24-hour culture treated with the Gram stain was colorless and became brown when counterstained with Bismarck brown. A check test with the same Gram stain on *Staphlylococcus albus* showed this organism definitely stained. Ordinary stains, like gentian violet, carbol fuchsin, methylene blue, and Bismarck brown were taken up readily. No irregular or involution forms have been seen.

CULTURAL CHARACTERS IN RELATION TO ACIDITY AND ALKALINITY

Methods.—In making up culture media the recent recommendations of the committee (Conn, II, '20) representing the American Bacteriological Society, as far as they go, were followed, with modifications as will be noted, and in addition other methods

and media were used which seemed worthy of trial. The aim has been to utilize the current methods of plant pathologists and at the same time take cognizance of technique employed by bacteriologists in general and by the medical men in particular.

The necessity of utilizing methods which are not commonly used by plant pathologists became evident early in the work, and having in mind the busy life of the ordinary pathologist, it will be necessary to indicate the reason for the adoption of any new scheme.

Using nutrient agar testing +10 or +15 on Fuller's scale (10 or 15 parts per 1000) the writer found that from diseased foxtail material he would at times obtain bacterial colonies which produced a very conspicuous reaction, a colorless zone followed by a marked whitish area (pl. 28, fig. 1), and then perhaps at the same time, on other plates, or at other times, using the same medium, colonies were obtained without any such features. Morphologically, the colonies as well as the individual bacteria appeared exactly alike, and inoculation experiments showed that both were pathogens producing the same kind of spot. Two explanations for this variation seemed plausible, first, that there existed 2 strains of the same species, one producing a precipitate and the other not, and second, that the conditions in the nutrient media were different. It was soon found that a colony that produced a white precipitate may, on transferring to another plate or tube, show no such character. It appeared therefore that there must be some slight difference in culture media even though it was made up at the same time and received the same treatment throughout.

In an effort to solve this, and mindful of the extensive data that were accumulating on hydrogen-ion concentration in relation to various phases of bacterial activity, the writer instead of titrating by the Fuller scheme, using phenolphthalein as the indicator, used the indicators recommended by Clark (II, '20) in which the color change with reference to acidity or alkalinity had been definitely worked out in terms of hydrogen-ion concentration. The color obtained by adding a few drops of indicator, like brom thymol blue, to a tube of melted, nutrient agar was then compared with the color chart given by Clark (following p. 40), and the color in the series for brom thymol blue matching best with the tube was taken as the hydrogen-ion concentration in terms of P_H. This of course is a rough way of measuring true

acidity or alkalinity but its superiority over Fuller's method soon became evident. Nutrient agar which gave a yellow or yellowish green color with brom thymol blue (those covering the reaction range of P_H 6.0–P_H 6.8 and therefore acid) when used as a substrate always showed colonies producing a colorless region followed by a dense precipitate, while agar which gave a blue color with brom thymol blue (those having a reaction of P_H 7 or over, hence neutral or alkaline) when used as the substrate showed colonies which never produced any precipitate.

The presence or absence of a colorless zone plus precipitate could then be controlled at will, depending on whether the medium was rendered slightly acid or slightly alkaline as measured by the hydrogen-ion concentration. Here then is a method of measuring acidity and alkalinity which is just as simple as Fuller's and much more accurate. By using this method the writer was able to obtain a character which immediately distinguished this bacterium from other similar-appearing organisms; in other words, using a medium of P_H 6.6, no matter what other white colonies might develop on a given plate, this organism could readily be recognized. (This power of producing a colorless zone and a white precipitate was an excellent character as a quick test for differential purposes).[1] The reason why Fuller's scale did not bring out this feature is apparent. A medium which tests +10 on Fuller's scale, and thus supposedly acid, is often, as will be shown later, really neutral or slightly alkaline. Besides this, it has been found that a medium which is slightly acid when it is prepared will change its reaction upon sterilization or upon standing. In particular the writer has found that nutrient agar kept in glass tubes of various "makes" will in time become alkaline.[2] This is especially true of much of the soft glassware obtained during the war, so that media that tested P_H 6 when made would, after two weeks, test P_H 7, and moreover, the same degree

[1] Miss Bryan (II, '21) has recently described a bacterial bud rot of cannas in which she shows the pathogen producing a colorless zone surrounded by a white precipitate on whey agar. Because of this similarity with the foxtail organism it was thought desirable to compare *Bacterium Cannae* with the foxtail pathogen. Miss Bryan very kindly furnished the writer with cultures of her organism. Comparison between the two show numerous differences, morphological and physiological, although as far as producing a precipitate is concerned they behave alike. The interesting thing about *B. Cannae* is that it produces a colorless area surrounded by a white precipitate not only on whey agar but also on ordinary nutrient agar possessing a slight acidity, as P 6.6. Furthermore, the production of this character can be controlled in the same manner as in the foxtail organism.

[2] Esty and Catheart (II, '21) have recently given some interesting data on the effect of different glassware on various solutions.

of change did not occur in different batches of tubes. New tubes in particular, even after hardening in several dippings of sulphuric acid-potassium dichromate cleanser and after several sterilizations in the autoclave, persisted in giving off considerable alkali. Hence in any series of 10 tubes, some made by one concern and some by another, or some old and others new, it was possible to obtain various acidities and alkalinities using the same medium. This in all probability is the reason for obtaining a series of poured plates with the same organism, some of the plates showing colonies with characteristic precipitate and others lacking in this feature. For the effect of autoclaving on the reaction of the medium see articles by Clark (II, '15, p. 130), Anthony and Ekroth (II, '16), Norton (II, '19) and Davis (II, '20). Besides glassware, other factors may change the reaction of a medium. Grace and Highberger (II, '20) noted changes in acidity, particularly in uninoculated glucose broth, and offered no explanation for the change. Foster and Randall (II, '21) found an increase in acidity of broth which they concluded was due not to a taking up of carbon dioxide, but to an opening up of the COHN groups as a result of the hydrolysis of the protein constituents.

Here it may be pointed out that not only has titration as measured by the hydrogen-ion concentration given more accurate results but the use of this method has stimulated careful analyses of physiological processes as related to active acidity or alkalinity with the discovery of numerous interesting and often valuable relationships, particularly with reference to human pathogens. A few instances will be cited. Clark and Lubs (II, '15) differentiated between organisms of the colon-aerogenes group by the use of indicators whose color changes were noted in terms of hydrogen-ion concentration. Ayers (II, '16) found that streptococci reached a more or less definite hydrogen-ion concentration in culture media, a fact which, he decided, helped in the classification of these bacteria. Later, in 1918, Ayers, Johnson, and Davis found that a non-pathogenic strain of *Streptococcus* reached a higher hydrogen-ion concentration than the pathogenic strains. They concluded that the difference in hydrogen-ion concentration may be used as one means of distinguishing non-pathogenic from pathogenic streptococci. Finally, Avery and Cullen (II, '19) found that they were able to distinguish human from bovine strains of *Streptococcus* because of the fact that human strains in nutrient broth develop a lower hydrogen-ion concentration.

They were thus enabled to differentiate between those organisms that may be pathogenic to man and those that are not.

Fennell and Fisher (II, '19), working with cultures of pneumococcus and meningococcus, were often unable to obtain suitable growth although the media utilized had apparently the same composition, was made in the same way, and the titration by the Fuller method was always adjusted to the same point, +0.2 (0.2 per cent). Using the hydrogen-ion concentration in their titration they obtained profuse and consistent growth. They found that pneumococcus has a very narrow range for optimum reaction, P_H 7.8 to P_H 8.0, which they considered as equal to +3.0 to +3.5 (3–3.5 per cent), "a total acidity far beyond anything previously suggested for the growth of pneumococcus." Norton (II, '19) obtained similar results.

Not only has the hydrogen-ion concentration been used successfully for distinguishing between closely related organisms, but its use in the study of various phases in metabolism has yielded valuable results. Its relationship to the growth of pneumococcus and meningococcus has just been pointed out. In addition it may be noted that Cole and Lloyd (II, '17) showed that among other factors, a suitable hydrogen-ion concentration is important for the cultivation of gonococcus. There are now numerous records like these which show the relationship of growth and development of many different micro-organisms to hydrogen-ion concentration. Concerning its relationship to definite physiological reactions there are also numerous records; for example, Bronfenbrenner and Schlesinger (II, '19) pointed out that the amount of acid and gas produced by bacteria depended on various factors, including the amount of carbohydrate, the amount of peptone, the amount of buffer, and on the hydrogen-ion concentration; Bigelow and Esty (II, '20) showed that a slight change in the hydrogen-ion concentration greatly affected the thermal death point, and Chambers (II, '20) gave accurate counts of the number of bacteria developed at different levels of hydrogen-ion concentration. Studies on non-pathogenic bacteria and fungi, as well as on higher plants, have shown similar relationships to hydrogen-ion concentration. The work of Allen (II, '19) on *Azotobacter*, Gillespie and Hurst (II, '18) on *Actinomyces scabies*, Rose (II, '19) on *Nummularia discreta*, and Duggar (II, '20) on nutrient solutions for higher plants, to mention but a few, has

shown the importance of hydrogen-ion concentration in the metabolism of numerous and diverse organisms.

Clark in 1915 summed up the matter as follows (p. 109): "The rate of enzyme action, the stability of colloidal structures upon which cellular life depends, the solubility of many physiologically important compounds, as well as the structure and composition of media and the color of the indicators used in the adjustment of their reactions all are dependent in greater or less degree upon hydrogen-ion concentration."

While it is absolutely essential that plant pathologists recognize the importance of the determination of hydrogen-ion concentration, yet it should be recognized that other factors are equally as important and when it is desired to know the buffer strength of a medium it even becomes necessary to use total acidity titration. That there is danger of attributing too much to hydrogen-ions has been pointed out in recent articles by Brown (II, '21[a]), Jones (II, '20), and Traube (II, '21).

In spite of the very considerable amount of data that has accumulated on this subject, many plant pathologists, as has already been stated, have paid little attention to it. With very few exceptions, Wolf and his associates in particular (II, '21), those who have dealt with bacterial plant pathogens have more or less completely ignored all the recent advances in this phase of bacteriology. Having presented data showing the necessity for determining the hydrogen-ion concentration of bacteriological media the writer will attempt to outline very briefly the principles involved and the methods used. This has already been done in a number of articles and books; the aim in presenting the matter here is to make available to plant pathologists the information at hand and to call attention to the more important references.

PRINCIPLES INVOLVED IN THE DETERMINATION OF ACID AND ALKALI

To define the terms acid and alkali in relation to the color reaction of some organic indicator is not satisfactory. Thus, to say that a solution is acid because it shows no color in the presence of phenolphthalein does not give much information, since by using another indicator, such as Congo red, the same solution may be said to be alkaline (see Washburn, II, '10). The satisfactory basis for a definition of acidity and alkalinity is furnished

by the ionic theory of Arrhenius (II, '13)[1]. According to this theory when a strong electrolyte dissolves in water in a dilute solution it is highly dissociated into two ionic groups. Hydrochloric acid, for example, breaks up into positive + H ions and negative — Cl ions, and sodium hydroxide breaks up into + Na ions and — OH ions. When a solution of hydrochloric acid is mixed with a solution of sodium hydroxide the hydrogen ions combine with hydroxyl ions to form water and in this union neutralization takes place. Pure water itself dissociates into + H and — OH ions, and the dissociation yields equal amounts of + H and — OH ions. A neutral solution may therefore be defined as "one in which the concentration of hydroxyl ions is equal to the concentration of the hydrogen ions. From this it follows that an acid solution is one in which the concentration of hydrogen ions exceeds that of OH ions, while an alkaline solution is one in which the concentration of hydroxyl ions exceeds that of hydrogen ions." Strong acids and alkalis like hydrochloric acid and sodium hydroxide are almost completely dissociated at certain concentrations, while weak acids like acetic acid and weak alkalis like ammonium hydroxide are only slightly dissociated.

The extent to which substances are dissociated into their ions may be determined by the hydrogen electrode and by other methods, and this determination, in which the hydrogen- and hydroxyl-ion concentration is definitely determined, becomes a measure of the acidity or alkalinity of the solution.

Normal solutions of hydrochloric acid and of acetic acid will neutralize the same amount of sodium hydroxide, but since hydrochloric acid is a strong acid it is almost completely dissociated, while the weak acetic acid is but weakly dissociated. The result is that normal hydrochloric acid, according to Michaelis (II, '14, p. 23), contains about 0.8 gram of hydrogen per liter, while normal acetic acid contains only 0.0043 gram of hydrogen per liter. The difference between the 2 acids may be noted in table I, taken from Michaelis (II, '14, p. 23).

As has already been indicated, water itself is an electrolyte and dissociates into + H ions and — OH ions. Sörensen determined that pure water at 22° C. contains a concentration of 1/10,000,000 of either ion, that is, that it contains 0.0000001 gram of H ions and the same amount of OH ions per liter. In other words

[1]This author, in a comparatively simple account, has summarized in English, the theories of solutions. The book is easy to read and is not burdened with mathematical formulae.

pure water is 0.0000001 normal acid and at the same time 0.0000001 normal alkali. Such fractions as 1/10,000,000 (0.0000001) being unwieldy, the logarithmic equivalents are used; thus 1/10,000,000 may be written 10^{-7}, and the hydrogen-ion concentration of theoretically pure water may then be written 10^{-7}, or expressed in the form of a negative logarithm as Sörensen does, $P_H 7$, which denotes the pressure of hydrogen ions (written variously pH, P_H, p_H^+, the last being Sörensen's original method [II, '09, p. 4]) or, in other words, the hydrogen-ion concentration.

TABLE I
H-ION CONCENTRATION OF STANDARD SOLUTIONS OF ACIDS

HCl at 18° C.			Acetic Acid at 18° C.		
Concentration	H-ion concentration	P_H	Concentration	H-ion concentration	P_H
Normal (1.0)	0.8	0.10	Normal (1.0)	4.3×10^{-3}	2.366
0.1 N	0.084	1.071	0.1 N	1.36×10^{-3}	2.866
0.01 N	0.0095	2.022	0.01 N	4.3×10^{-4}	3.366
0.001 N	9.7×10^{-4}	3.013	0.001N	1.36×10^{-4}	3.866
0.0001N	9.8×10^{-5}	4.009			

At a given temperature the product of the concentration of H and OH ions is constant and this value is called the "dissociation constant." For pure water at 22° C. this is equal to 10^{-14}, since, as has already been stated, the concentration of H ions and of OH ions is each equal to 10^{-7}. As the dissociation constant at a given temperature is always the same, the concentration of either +H or —OH can be expressed in terms of the other. Thus 1/100 N hydrochloric acid which has an hydrogen-ion concentration of 10^{-2} and an hydroxyl-ion concentration of 10^{-12} is said to have a value of P_H 2. Similarly, a 1/100 N sodium hydroxide solution which has an hydroxyl-ion concentration of 10^{-2} and an hydrogen-ion concentration of 10^{-12} has a value of P_H 12. All acids having a greater hydrogen-ion concentration than pure water have a value less than P_H 7 (the smaller the logarithmic exponent of a number less than 1 the greater the number); conversely all alkaline solutions having a lower hydrogen-ion concentration than pure water have a value greater than P_H 7. Table II adopted with modifications from Medalia (II, '20, p. 433) may help in an understanding of the matter.

Good accounts of the principles involved in hydrogen-ion concentration may be had in the following: Sörensen (II, '09), Wash-

burn (II, '10), Michaelis (II, '14), Clark (II, '15, '20) and Committee on Descriptive Chart for 1918 (II, Conn, '19).

TABLE II

RELATION OF P_H VALUES TO STRENGTH OF SOLUTION

Strength of solution	Grams of hydrogen per liter	Expressed logarithmically	P_H value	
Normal HCl	1.0	10^{-0}	0.0	Acid
1/10 N HCl	0.1	10^{-1}	1.0	Acid
1/100 N HCl	0.01	10^{-2}	2.0	Acid
1/1000 N HCl	0.001	10^{-3}	3.0	Acid
1/10000 N HCl	0.0001	10^{-4}	4.0	Acid
1/100000 N HCl	0.00001	10^{-5}	5.0	Acid
1/1000000 N HCl	0.000001	10^{-6}	6.0	Acid
Pure water	0.0000001	10^{-7}	7.0	Neutrality
1/1000000 N NaOH	0.00000001	10^{-8}	8.0	Alkaline
1/100000 N NaOH	0.000000001	10^{-9}	9.0	Alkaline
1/10000 N NaOH	0.0000000001	10^{-10}	10.0	Alkaline
1/1000 N NaOH	0.00000000001	10^{-11}	11.0	Alkaline
1/100 N NaOH	0.000000000001	10^{-12}	12.0	Alkaline
1/10 N NaOH	0.0000000000001	10^{-13}	13.0	Alkaline
Normal NaOH	0.00000000000001	10^{-14}	14.0	Alkaline

METHODS OF MEASURING HYDROGEN-ION CONCENTRATION

The hydrogen-ion concentration, that is, the true acidity of a solution, may be measured in various ways. The two common methods used are, first, by measuring the electromotive force of a solution, and second, by the use of certain indicators whose color changes in relation to various levels of hydrogen-ion concentration have been definitely determined by the first method. The first or electrometric method, with good equipment, is more accurate, while the second or colorimetric method, while not as accurate, is much more available, since the cost is much less, and its operation very much more simple. (The writer having seen both in operation is satisfied that for ordinary work, and even for special research, the first is not essential for a bacteriologist.) For references to methods and apparatus necessary for electrometric measurements see Clark (II, '20) and Leeds and Northrup Company, Catalogue No. 75 (II, '20).

Indicators developed by Clark and Lubs ('17) for colorimetric work are especially well fitted for bacteriological media since they are as a whole brilliantly colored, their color changes at different levels are marked, and they are readily procurable at reasonable rates. Their color changes with reference to hydrogen-ion con-

centration have been carefully ascertained by Clark and Lubs and the values given by these authors have been checked up by numerous investigators. Explanation of the colorimetric method may be had in Friedenthal (II, '04), Salm (II, '04), Sörensen (II, '09), Clark (II, '15, '20) and Committee on Descriptive Chart for 1918 (Conn, II, '19).

STANDARDS FOR COMPARISON

Having added a few drops of an indicator, like brom thymol blue, to a tube of nutrient broth, how is the P_H value to be determined? The writer has already indicated one method, namely, comparing the tube with the color chart given by Clark (II, '20). This method for general laboratory work was found very satisfactory; the error was small, particularly if the solution was not highly colored; it was comparatively easy to manipulate and could be used readily in the class room; and best of all, it was very simple and comparatively inexpensive. The errors involved in this method are: first, it is difficult to get 2 charts which exactly agree in the shades of color for any one indicator, second, any color in the solution to be tested interferes with the color of the indicator. Nevertheless, in the absence of definitely known standards, this method is to be preferred, in the opinion of the writer, to the method advocated by the Committee on the Descriptive Chart (Conn, II, '20). This committee recognized the value of the Clark and Lubs indicators but instead of using anything for comparison, they simply recommend the following: "Bring the media to such an acidity as to turn this indicator (brom thymol blue) a distinct grass-green (neither yellow green nor blue green)."

It is evident from what has been said that it is desirable to have some standards whose hydrogen-ion concentrations have been definitely ascertained. Standards such as those recommended by Clark and Lubs contain certain salts, such as borates, phosphates, phthalates, which in the presence of certain indicators present definite colors. (The hydrogen-ion concentration of these standards having been previously determined by Clark and Lubs and by others using the electrometric method, it thus becomes possible in performing a titration to obtain a series of solutions of known hydrogen-ion concentrations which possess definite colors at certain levels of hydrogen-ion concentration.) The standards largely developed by Sörensen, recommended by

Clark and Lubs, and in common use are difficult and laborious to make, but for careful work, are apparently indispensable. Using these standards and a comparator block, it is a simple affair to compare a tube of media containing a certain indicator with another tube containing the standard solution plus the same indicator. This method, slightly modified by placing a tube of clear water before the solution to be tested and a tube of the unknown solution without indicator before the standard, as recommended by various investigators, has been extensively used by the writer in this investigation. The procedure is fully described by Clark (II, '20).

Various devices designed to simplify the procedure in making standards have appeared; most of these consist in reducing the number of standard solutions, which in some instances, also reduce the range of P_H values (see McIlvaine, II, '21). One of the simplest of these, judging from the description, is the one advocated by Acree and his associates (II, '21). The writer has not been able to use this. Other attempts to reduce the labor involved in making standards consist in varying the number of drops of indicator in a series of tubes containing simply a few cubic centimeters of acid and of alkali. This was first recommended by Barnett and Chapman (II, '18) and later amplified by Medalia (II, '20) and by Gillespie (II, '20). Bunker and Schuber (II, '22) claim good results by this method, and it is the one recommended by the American Public Health Association in the "Standard Methods for the Bacteriological Examination of Milk," 1921.[1]

BUFFERS

Standard solutions used for comparison with unknowns are often called "buffers." What is a "buffer"? Any solution which resists change in hydrogen-ion concentration upon the addition of acid or alkali is called a "buffer." It is of course desirable that standard solutions once made up should retain their calculated hydrogen-ion concentration as long as possible, and certain salts in particular are chosen for standards because of their marked resistance to change in hydrogen-ion concentration, even after standing for several months. Not only do a large number of organic and inorganic salts act as buffers but many other sub-

[1]Ready prepared standard solutions are advertised by La Motte Chemical Products Company, 13 W. Saratoga St., Baltimore, and by Graham Chemical Company, 100 Rockingham Street, Rochester, N. Y. The latter concern sells the product developed by Acree and his associates ('21).

stances, such as peptone, beef extract, blood, etc., act in a similar manner. A good account of buffer action appears in Clark's work (II, '15, p. 116).

COMPARISON BETWEEN FULLER'S SCALE AND HYDROGEN-ION CONCENTRATION

Having briefly and perhaps inadequately described what is meant by hydrogen-ion concentration and how to measure it, the next question worthy of attention is, how does the older titration method, such as Fuller's (II, '95), compare with the determination of hydrogen-ion concentration. There are two main reasons why the two methods yield different results; first, the difference in degree of dissociation of different electrolytes; and, second, the buffer action of various substances. As previously described, when equal amounts of normal solutions of hydrochloric and acetic acids are titrated the same amount of alkali is utilized, although the two acids have entirely different P_H values, since one dissociates very strongly and the other but weakly; that is, titrating with sodium hydroxide, in the case of weak acids, gives no indication as to the actual acidity or the hydrogen-ion concentration. When a nutrient medium is neutralized with strong alkali the figure obtained gives no indication of the actual acidity present in the medium but gives an expression of the total acidity, including the "active" acidity and the "reserve" acidity, and this "reserve" acidity remains an unknown quantity made up of undissociated acid molecules as well as the acid held in union by the buffers present in all ordinary nutrient media. Titrating with sodium hydroxide then gives a measure of the total acidity, while the hydrogen-ion concentration measures the true or "active" acidity.

Why is it insufficient to titrate for total acidity? The following illustration taken from Sörensen (II, '09) answers this question. He and other investigators found that certain enzymes, such as invertase, catalase, pepsin, and others, show optimum activity in the presence of a certain amount of acid, but the quantity of acid necessary for this activity could not be definitely ascertained by the ordinary titration method. The reason for this is clear. A solution of an enzyme, such as invertase, contains substances which are capable of combining with acids, so that the optimum acidity depends, for one thing, on the substances, buffers, going with the enzyme. However, without measuring the hydrogen-ion concentration it is not possible to get a measure of the exact

amount of these substances so that it becomes impossible to indicate the optimum degree of acidity which would be the same under all experimental conditions. On the other hand, obtaining a measure of the acidity by means of the hydrogen-ion concentration, it is possible to show that this is constant and is as definite as the nature and quantity of the enzyme. Thus, while the total acidity necessary to give optimum enzyme action is very different for 3 enzymatic solutions, the optimum concentration of hydrogen ions, on the other hand, is the same for all 3.

Using a similar illustration for bacteriological media, it may be said that while the optimum acidity for the growth of a particular organism may be +15 on a medium containing Witte's peptone, it will be different on a medium containing some other peptone. When an organism is found to respond best to a reaction of P_H 7, it will always respond similarly at that reaction no matter what the peptone may be, other things remaining the same. Occasionally it becomes important to know the buffer value of the media and in such cases a determination of the total acidity by ordinary titration is utilized in conjunction with a determination of the hydrogen-ion concentration. Illuminating articles on the buffer values of different peptones have been written by Bronfenbrenner, DeBord, and Orr (II, '21) and by Brown (II, '21).

Titration (Fuller's scale)	P_H
+ 7.5	7.5
+ 8.0	7.4
+10.0	7.5
+11.5	7.1
+12.5	7.4
+14.0	6.8
+14.5	6.8
+15.0	6.9

Not only are different results to be expected because of the difference in principles in titrating for total acidity as compared to a determination of hydrogen ions, but total acidity measurements, such as the procedure involved in calculating Fuller's scale, are rather inaccurate for other reasons. As Clark (II, '15) has stated, the use of phenolphthalein as indicator, titrating when the medium is hot, and the difference in end point used by different investigators due to lack of proper color standards, all tend to make the ordinary titration method variable and inexact.

Since Fuller's scale has had such common usage it seems desirable to present actual comparisons of this scale with the determination of hydrogen ions. Various investigators have given comparative figures, the table given by Norton ('19) and reproduced above, is one illustration of such comparison in bacteriological culture media.

The titrations were made by the ordinary methods using phenolphthalein as indicator. Attention should be called to the fact that figures under titration represent parts per thousand as recommended originally by Fuller instead of parts per hundred as is used by Norton.[1] It will be noted that while the total acidity titration (Fuller's scale) shows the media to be markedly acid, the acidity in terms of hydrogen-ion concentration is very nearly neutral or even alkaline. Figures obtained by me show the same thing. A few are here listed:

	P_H	Fuller's scale
Nutrient beef broth acidulated with 0.1% citric acid	4.8	+24.0
Nutrient beef broth acidulated with 0.05% hydrochloric acid	5.5	+12.0
Nutrient beef broth neutralized with sodium hydroxide	7.0	+10.0
Nutrient beef broth rendered alkaline with sodium hydroxide	7.2	+ 6.0

Here also a medium which is neutral or even alkaline with reference to hydrogen-ion concentration appears acid in Fuller's scale. This of course is not surprising since, as is now well known, the color change of phenolphthalein instead of being at the neutral point, is actually on the alkaline side, between P_H 8 and P_H 9.6, so that media below P_H 8 would appear acid if this indicator is used. It is necessary to emphasize the fact that these comparisons are merely indications of what differences may be expected. Any changes, such as the amount or kind of peptone or of beef extract, will change the value on Fuller's scale even in the presence of the same amount of acid. In these comparisons the medium used consisted of 3 grams of Liebig's beef extract, 10 grams of "Bacto" peptone, and 1000 cc. of distilled water.

GROWTH OF THE FOXTAIL ORGANISM ON VARIOUS MEDIA

Two different kinds of agar were used, the Difco powdered agar and a shredded agar of unknown make. No difference in growth was noted but the first is to be preferred since it is more readily soluble. Difco peptone was used and two different kinds

[1] A discussion of the difference in interpretation of Fuller's scale is given by the writer in another publication (Rosen, II, '22).

of meat extract, dehydrated Bacto beef, and Liebig's meat extract. The dehydrated beef gave better growth but required much longer time to make and resulted in a turbid, dirty product, making hydrogen-ion determinations by indicators very difficult.

Agar Plates.—On peptone-beef agar poured plates, P_H 6.6, kept at 20° to 25° C., colonies appeared within 48 hours. They were white, round, smooth, and in 4 days well-separated surface colonies measured as much as 6 mm. in diameter. At first they showed a bluish tinge but later they became opaque white with a somewhat faintly colored creamy yellowish center. The margin was entire, with a conspicuous colorless zone 2 to 4 mm. wide surrounded by a marked whitish discoloration of the medium which was most conspicuous at the border of the colorless zone and gradually faded out into the color of the surrounding medium. The whitish discoloration might be recognized at a distance of 0.5 cm. from the colorless zone at the end of the fourth day although it was faint at this distance. The colony was somewhat sticky to the touch of a needle but was not viscid; it was glistening, somewhat raised or convex, and internally appeared amorphous, that is, without distinctive markings. As the medium dried out the colonies became indistinct and gradually disappeared from view. Buried colonies made but little growth. On P_H 7.2 peptone-beef agar growth was the same but there was no colorless zone or precipitate.

Agar stroke.—At 25 to 30° C. there was a moderate amount of growth in 48 hours, often reaching a width of around 4 mm. at the base of the slant and tapering upwards. The growth was filiform, raised, glistening, smooth, and opaque white to creamy white, odor was absent or not marked, and the consistency was that of melted butter. Growth was very marked at the base of the slant and in the water of condensation and of syneresis. As the smears became old there was a tendency to form a slight, thin growth at the margin which upon close examination appeared in the form of irregular, fine, thread-like projections. Below P_H 7, a colorless region surrounded the smear and this region in turn was bordered by a dense white precipitate. This precipitate became very marked by the third or fourth day. Above P_H 7 there was no colorless zone or precipitate.

Agar stab.—There was good growth at the surface and slight growth in the upper part of the stab. There was no growth in the lower part of the stab.

Gelatin plates.—On poured plates, kept at about 20° C., testing P_H 6, colonies appeared slowly. In 48 hours they were barely visible, being in the form of fine white points. By the fifth day well-separated surface colonies measured 1.5 to 2.5 mm. in diameter; they were round, the margin was entire, appearing coarsely granular when viewed with the low power of a microscope; the granules were not arranged in any definite pattern but were somewhat larger toward the middle of the colony. The color was glistening white with a bluish lustre towards the margin and a yellowish tinge in the middle. There was no liquefaction and no odor. In contrast to surface colonies, which possess even margins, colonies which were imbedded presented uneven margins, and were often deeply lobed. These colonies appeared very rough under the microscope, and the granules were much larger than those of surface colonies. Imbedded colonies were also much reduced in size. On P_H 7 gelatin plates the growth was the same as on P_H 6 gelatin. As the colonies advanced in age the granulation so evident up to the fifth day gradually disappeared. When plates were kept at 25° C., a temperature which caused a slight softening of gelatin testing P_H 6–7, the growth was noticeably better, well-scattered colonies measuring 5 to 6 mm. on the seventh day; as the gelatin softened the surface colonies sank into the medium and took on concentric striae, a character not evident on firm media. Even after 2 months there was no liquefaction. In contrast to gelatin testing P_H 6.0 and P_H 7.0 there was no growth on gelatin testing P_H 5.5 (P_H 8.2 gelatin refused to gel when it has been rendered alkaline before sterilization). On gelatin growth as a whole was not as good as on agar but it should be noted that this might be due to the comparatively low temperature at which gelatin is kept, the organism being one which grows best at a comparatively high temperature. No colorless zone with white precipitate has been noted on gelatin.

Gelatin stabs.—Growth was visible only in the upper part of the stab. There was no liquefaction.

Plain gelatin stabs.—As there is a possibility that the peptone and beef extract of nutrient gelatin may interfere with the enzymes which liquefy gelatin, stabs were made in a medium containing no nutrients except the 1.5 per cent gelatin. On these the growth was but slight and in the upper part of the stab. Here also there was no liquefaction.

Nutrient broth.—Peptone-beef broth testing P_H 7 at 25° C. produced but a faint surface growth and a slight clouding of the medium in 24 hours. In 48 hours the surface growth was more definite and there was a marked clouding throughout the medium, there was no odor, and there was a flocculent sediment. By the end of the sixth day there was a marked surface growth as well as an irregular, granular growth in the upper part of the medium. On agitation these readily broke up into very finely divided flocculent particles. In old cultures there was a heavy sediment which when agitated rose in thread-like whorls and was broken up with difficulty. (One per cent of peptone was but slightly better than 0.5 per cent.).

Nutrient broth over chloroform.—As compared to growth in nutrient broth in the usual atmosphere, growth in an atmosphere of chloroform was much restricted, there was no surface growth and only faint clouding, but the sediment was the same in amount and kind.

Nutrient broth plus alcohol.—Absolute alcohol was added to nutrient broth in sufficient quantity to make solutions of 4, 5, 6, 7, 8, and 9 per cent. There was no growth in any tube above 4 per cent at the end of 10 days. While this gives no exact information on the actual percentage of alcohol which may inhibit growth, no provision having been made for the volatilization of the alcohol or to account for any combination with substances contained in nutrient broth, it nevertheless indicates the inhibiting action of this substance at relatively low concentrations and is quite comparable to the results obtained by others on non-spore-forming organisms.

Sodium chloride in nutrient broth.—One per cent sodium chloride had no marked influence on growth; with 2 per cent there was a reduction in growth and when 4 per cent was reached there was no growth. In 2 and 3 per cent broth there was a marked tendency to form long streamers which hung down from the surface and broke up slowly when shaken. This character is doubtless in the nature of a response to unfavorable, high, osmotic concentrations and indicates a tendency of the organism to remain united in chains and in clumps under such conditions.

Toleration of acids.—The acids used were acetic, citric, hydrochloric, malic, phosphoric, and tartaric. Various investigators have concluded that the germicidal effect of acids may be due to one or more of the following factors: the hydrogen ions, the

anions, and the undissociated molecules, the last 2 often being considered as important in the action of organic acids. The subject has received considerable attention and good summaries may be had in articles by Chambers (II, '20), Foster and Randall (II, '21), Schoenholz and Meyer (II, '21), and Wolf and Shunk (II, '21, pp. 14–20). It is of course clear that there is very little significance in simply adding 0.05 or 0.1 per cent of the acids employed without ascertaining what the active acidity of the media has become. When this acidity is measured it is then possible to compare fairly accurately the effect of one anion with another, at least at the same hydrogen-ion concentration. The writer has endeavored to follow out the old methods by measuring out 0.05 and 0.1 per cent of acid, adding this to nutrient broth, and then ascertaining by colorimetric comparisons what the hydrogen-ion concentrations are. Comparatively equal amounts of inoculum, 0.1 cc. of suspension from broth cultures 48 hours old, were used in the experiments made in Jena glass tubes, having ascertained that these tubes had no appreciable effect on the P_H value after sterilization. Twenty cc. of medium were used in each tube. The broth was rendered neutral, P_H 7, with sodium hydroxide before sterilization (tests after sterilizing exhibiting the same P_H). The acids were added aseptically after sterilization, the tubes being then incubated for 48 hours before inoculation in order to make certain that contaminations had not occurred.

TABLE III

EFFECT OF ACIDS ON GROWTH, MEDIUM NUTRIENT BROTH

Acid	Per cent	H-ion concentration of medium	Growth at end of 48 hours	Growth at end of 6 days	Growth at end of 9 days
Acetic	0.05	4.9	None	None	None
	0.1	4.8	None	None	None
Citric	0.05	5.0	Good	←	←
	0.1	4.8	None	None	None
Hydrochloric	0.05	5.5(?)	Very good	←	←
	0.1	4.5	None	None	None
Lactic	0.05	5.0	Good	←	←
	0.1	4.8	None	None	None
Malic	0.05	5.0	None	Fair	Good
	0.1	4.7	None	None	None
Phosphoric 85%	0.05	4.9	None	None	None
	0.1	4.3	None	None	None
Tartaric	0.05	4.9	None	Fair (1 out of 3)	←
	0.1	4.5	None	None	None

From table III there is a slight suggestion that acetate and phosphate ions are markedly injurious to growth, while malate and tartrate ions exercise a very retarding influence; in contrast to these the citrate, chloride, and lactate ions have no marked effect. It should be noted that there was no growth in any of the acids tried at the end of 24 hours although neutral broth kept at the same temperature, 25° C., showed marked clouding at the end of that period. This is to be expected since this organism in nutrient broth grows best around the neutral point, between P_H 6 and P_H 8. It is rather surprising to see the phosphate act as a poison and this perhaps needs to be repeated before accepting the result although the work was done carefully and carried out in triplicate. More will be said of this later. As far as the acetate is concerned the result obtained substantiates the findings of others (see, for example, Wolf and Shunk [II, '21, pp. 14–20]).

TABLE IV

CHANGE IN P_H AFTER 10 DAYS GROWTH IN ACID BROTHS

	Original P_H	Final P_H
Citric acid	4.9	7.4
Hydrochloric acid	5.5	7.4
Lactic acid	5.3	6.8
Malic acid	5.0	6.8

Table IV is of interest not only because it shows the production of alkali in this medium, a marked character of this organism, but also because it shows that in a given period of time the final hydrogen-ion concentration is not necessarily the same even though the initial concentration may have been quite similar. It is seen that there are apparently 2 groups, one developing an alkalinity of P_H 7.4, and the other shifting only to P_H 6.8. Why lactic acid should produce a higher final hydrogen-ion concentration than citric acid is a question; perhaps this is due to a difference in the dissociation of salts formed, but in the case of malic acid this is doubtless coupled with a lower amount of growth in the same time period (see table III).

It has already been noted that media will change on standing and that changes may be due to glassware or to some rearrangement in the chemical make-up of the medium. The changes as noted in table V are not very great; yet in some of these it is such that if the hydrogen-ion concentration were the only limiting factor the organism ought to grow in the changed medium.

TABLE V

CHANGE IN P_H OF ACID BROTHS AFTER STANDING 10 DAYS UNINOCULATED

Acids	Original P_H	Final P_H
Acetic	4.9 4.8	5.3 4.8
Citric	5.0 4.8	5.3 5.0
Hydrochloric	4.5	5.0
Lactic	4.8	5.0
Malic	4.7	5.0
Phosphoric	4.9 4.3	5.2 4.8
Tartaric	4.9 4.5	5.3 4.6

For example, citric acid broth changed from P_H 4.8 to P_H 5.0, an hydrogen-ion concentration not sufficient to prevent growth (see table III), yet when citric acid broth testing P_H 5.0, originally P_H 4.8, is inoculated there is no growth. The same is true for lactic, malic, and tartaric acids. Without more experimental data it is not possible to give an acceptable explanation of the change, which in this whole series is toward the alkaline side. There is of course some possibility that even with Jena glass there is a slight amount of alkali produced, particularly in strongly acid media; other possibilities such as the production of compounds in which a greater proportion of OH ions is set free may also be considered.

To test further the effect of the anion of various acids, 0.5 cc. of 0.405 N sodium hydroxide was added aseptically to 20 cc. of such acid media as had previously given no growth. (The alkali had first been sterilized so that there was no need of autoclaving after it had been added.) The results are shown in table VI.

Table VI, in comparison with table III, brings out very sharply the poisonous effect of the acetate anions when the hydrogen ions are not the limiting factors. However, it would appear, judging by the results of the phosphoric acid tests, that there may be limiting factors other than the cation and the anion. For one thing, it is hard to believe that the phosphate radicle, as such,

TABLE VI
ACID BROTHS WITH ALKALI ADDED

Acid	Per cent	P_H after addition of alkali	Growth at end of 10 days
Acetic	0.05	7.0	Good
	0.1	5.7	None
Citric	0.1	6.0	Good
Hydrochloric	0.1	7.4	Good
Lactic	0.1	7.0	Good
Malic	0.1	6.0	Good
	0.05	7.0	Good
Phosphoric	0.1	5.8	Good
Tartaric	0.1	6.2	Good

has any poisonous action in the concentrations used (see account of growth in Fermi's solution). Of course, the undissociated molecule may play the role of poison but this also fails to give a convincing explanation of the action. The specificity of the organism with relation to phosphate may be a factor but this is merely assumption; there may be some chemical rearrangement involved which has not been previously recognized, or the action may be a physical one involving such phenomena as surface tension. Traube (II, '21), for example, believes that surface tension should be considered as entering into the action of acids and bases.

In order to test the effect of autoclaving, acids were added to the medium before sterilizing. Approximately 15 pounds pressure for 20 minutes was used. The following acids were employed: citric, hydrochloric, lactic, malic, phosphoric, and tartaric. They were added to nutrient broth in amounts so as to make 0.1 and 0.2 per cent by volume. In every case the hydrogen-ion concentration, ascertained after sterilizing, was the same in each acid, and at both 0.1 and 0.2 per cent it was P_H 5.2. (The nutrient broth in this case contained dehydrated beef instead of Liebig's beef extract, which was used in the acid experiments previously reported.) No growth was obtained in any of the acid media, either at 0.1 or 0.2 per cent, while the same medium without acid showed excellent growth.

Comparison between cotton and glass wool as filtering agents.—In 1916 Miss Lloyd reported that certain substances necessary for growth of *Meningococcus* were removed when filtering was

done through filter-paper in contrast to glass wool which, when used as a filter, did not absorb these substances. Since the filtering done by the writer, and as commonly practiced, is through absorbent cotton, it seemed desirable to test the effect of glass wool as compared with cotton on the growth of the foxtail organism. Using nutrient agar, adjusted to P_H 7, as the medium no difference in growth was detected, and in another series in which it was desired to obtain a comparison between distilled water and tap water in a medium of nutrient agar each kind of medium was divided into 2 parts, 1 filtered through cotton and the other through glass wool. No difference in growth was evident either when tap water was contrasted with distilled water or when glass wool was used instead of cotton. In still another series, using nutrient agar as the medium, the 2 different filtering agents were used and part of the medium sterilized by the intermittent process in the Arnold sterilizer and the other part sterilized in the autoclave at 15 pounds pressure for 30 minutes. It was thought that if any "growth accessories" or "hormones" were involved a difference in sterilizing temperatures in conjunction with different filtering agents might show a difference in growth, but no difference was observed. It may perhaps be concluded that the foxtail organism does not respond to "growth accessories" although further work is necessary before this is accepted.

Loeffler's blood serum.—Growth restricted, whitish, glistening, filiform, slightly raised, and smooth; the medium was not liquefied.

Lima bean agar slants.—Growth in this medium was excellent; it was fully as good, if not superior, to any other medium tried, and bears out the suggestion made by others of making greater use of vegetable media in the study of bacterial pathogens. (The medium consists of 100 grams of dry lima beans, 15 grams of agar, and 1000 cc. of distilled water.) The beans were cooked until they readily fell apart and were strained through cheesecloth, the cloth being squeezed so that all the available liquid was recovered. (The medium as it finally appeared was rather turbid.) At 30° C. there was marked growth in 48 hours; it was raised, glistening, whitish, filiform, and there was no colorless zone or precipitate (P_H value not tested). As the culture became several days old a slight pinkish color developed in the smear, which was particularly noticeable at the base of the slant.

Corn meal agar slants.—Growth not as good as on lima-bean agar (ingredients in the same proportion as in lima-bean agar); it was filiform, quite the same whitish color as that possessed by the medium itself, and somewhat raised and glistening.

Whey agar slants.[1]—Growth at 30° C., medium testing P_H 5.4, was good; it was raised, filiform, ivory-yellow in color (see Ridgway, Color Standards, 1912), glistening, margin slightly undulating or entire, odor none, consistency slimy in the moist part at the base of the slant, and butyrous, somewhat sticky, in the remainder; there was a tendency to produce small, inconspicuous warts which appeared as whitish dots in a vitreous, ivory-yellow matrix. Surrounding the smear there was at first a colorless zone followed by a white precipitate, but by the fourth day the colorless area disappeared, due to an extension of growth at the margin overgrowing the area. The margin finally appeared markedly white in contrast to the interior, this whiteness being due to the white precipitate which had previously been formed when the smear was narrower. (By carefully removing the bacterial smear it was seen that the white portion coincided with the region where precipitate had been formed.) Growth on whey agar slants testing P_H 7.0 and P_H 7.2 was slightly better than on P_H 5.4 medium, but there was no colorless region and no precipitate. On P_H 9.0 whey agar there was no growth.

Uschinsky's solution.—Very slight growth in 3 days kept at 30° C., medium testing P_H 7.6; at the end of 10 days there was a marked ring with a faint surface growth and the fluid was rendered markedly viscid.

Fermi's solution.—Noticeable surface growth in 3 days which broke up into very fine particles on agitation and left a ring around the tube; there was but slight clouding. At the end of 7 days there was a very marked surface growth and a dense clouding in the upper two-thirds of the medium.

Cohn's solution—No growth.

Potato cylinders.—Growth at 25–30° C. good, glistening, buckthorn-brown (Ridgway), sticky, slightly viscid. After growth of 1 month the cylinders were macerated without difficulty, 10 cc. of distilled water was added to each tube, and, in addition, 1 cc. of potassium iodide. A reddish purple color immediately developed which upon standing for several hours entirely disappeared,

[1]Made up according to the formula given by Miss Bryan (II, '21, p. 149) except that Bacto-gelatin was used instead of Nelson's photographic gelatin, No. 1.

leaving a colorless mass; this was in contrast to uninoculated cylinders and in cylinders upon which *Bacillus Coli* was grown, in which the color remained deep blue.

Nutrient broth plus 1 per cent potato starch.—At the end of 11 days, 1 cc. of alcoholic solution of iodine was added and a reddish blue color developed which disappeared after standing over night. (*B. Coli* growth remained deep blue).

Nutrient agar plus 1 per cent potato starch.—Smears were made across the middle on plates containing nutrient agar plus starch. At the end of 10 days plates were flooded with a potassium iodide solution resulting in a clear zone about 0.5 cm. wide around the smears, while the remainder of the plates were deeply colored. All 3 of the last experiments reported indicate a strong diastatic action.

Potato-dextrose agar slants.—Growth good, white, glistening, not viscid but somewhat sticky, best at the base of the slant, noticeably flatter than on ordinary nutrient agar, margin even, somewhat spreading.

Milk.—By the sixth day, at a temperature of 25–30° C., there was no coagulation and no clearing. By the eighth day there was a color change from light buff to warm buff (Ridgway). The medium was cleared slowly but there was no coagulation and by the end of 8 weeks most of the fluid was clear, clay-colored, with a somewhat slimy coagulum covering the bottom of the tube which, when agitated, broke up into lumps. At the end of 3 months most of the coagulum disappeared.

Litmus milk.—There was no change in color up to the fifteenth day when the medium began to turn blue at a temperature of 25–30° C. (original color a grayish blue). The behavior was otherwise the same as in plain milk.

Methylene blue in milk.—Reduction of the dye was prompt; in 24 hours the blue disappeared from the lower two-thirds of the medium leaving a blue rim above. By the end of 48 hours almost all of the blue had disappeared. Here also there was no curdling, indicating that no lab ferment (chymosin or rennin) was produced. This is further indicated by the fact that gelatin was not liquefied.

Grass decoction agars.—It seemed desirable to test the effect of different grass decoctions on growth, in particular the effect of grass decoction obtained from a susceptible host as compared with a decoction obtained from a resistant host. For this purpose

500 grams of washed, healthy leaves of *Chaetochloa lutescens* and of *C. viridis* were boiled in distilled water for 1 hour, the extract decanted, and the well-cooked leaves squeezed between cheese-cloth in order to obtain a maximum amount of extract. Fifteen grams of agar were added and enough water to make one liter of each decoction. The growth on slants of both of these decoctions was meager and no difference was detected. The experiment indicates that between 2 different cooked decoctions, 1 of a resistant and the other of a susceptible plant, there was no difference in growth, and it is felt that further than this no conclusion seems justified.

Amino acids in relation to growth.—Time has not permitted a thorough study of the role of amino acids in the growth of the foxtail organism, but the experiment here reported is indicative of a line of work that should be fully investigated.

TABLE VII

AMINO ACIDS IN RELATION TO GROWTH

Solution	P_H	Response
(1) 0.1% tyrosine*	4.6	No growth
(2) 0.1% tyrosine + 1.0% dextrose	4.6	No growth
(3) 0.1% tyrosine + beef extract	--------	Noticeable clouding
(4) 0.1% tyrosine + 1.0% dextrose + beef extract	--------	Heavy growth
(5) 0.1% leucine	6.8	Noticeable clouding
(6) 0.1% leucine + 1.0% dextrose	--------	Clouding more pronounced than in (5)
(7) 0.1% leucine + beef extract	--------	Better growth than in (6)
(8) 0.1% leucine + 1.0% dextrose + beef extract	--------	Growth as good as in (13)
(9) 0.1% leucine fraction (alanine, leucine, valine)	--------	Clouding more pronounced than in (5)
(10) 0.1% leucine fraction + 1% dextrose	--------	Marked clouding, better than (6) and (9)
(11) 0.1% leucine fraction + beef extract	--------	Growth about same as in (7)
(12) 0.1% leucine fraction + 1.0% dextrose + beef extract	--------	Growth somewhat superior to (13)
(13) nutrient broth (1.0% peptone + 3 grams beef extract)	--------	Good growth

*The amino acids utilized were kindly supplied by Dr. Barnett Sure.

It should be explained that the amino acids were dissolved in distilled water, and in the case of tyrosine, hydrochloric acid was added in (1) and (2) to aid in dissolution, the amount of acid added being sufficient, as shown by the P_H obtained, to affect growth. The beef extract (Liebig's) was used in the same pro-

portion as was used in nutrient broth, 3 grams per liter. The various solutions were sterilized in the autoclave at about 12 pounds pressure for 20 minutes. The experiment clearly indicates that the foxtail organism not only utilizes amino acids but that growth is influenced by the type of amino acid present, thus the combination of alanine, leucine, and valine yields better growth than leucine alone, although the total amount of amino acid used was the same in both solutions. As compared with peptone (Difco) it is interesting to note that these amino acids in combination with dextrose and beef extract gave just as good a growth, and in case of the leucine fraction, the growth seemed heavier than in peptone media.

Indol production.—Both the sodium nitrite-sulphuric acid and the Ehrlich tests gave negative results at the end of the second, fourth and tenth days. The media used were Dunham's solution, nutrient broth, and one consisting of 1 per cent peptone, 0.5 per cent disodium phosphate and 0.1 per cent magnesium sulphate in a liter of distilled water. (*Bacillus Coli* gave a positive test in Dunham's solution at end of the fourth day, with Ehrlich's test.) It should be noted that according to the recent work of Norton and Sawyer (II, '21) it appears that the old tests, such as sodium nitrite-sulphuric acid, are not reliable.

Nitrite production.—Growth in nitrate broth was fairly good; within 48 hours there was a slight growth on the surface, a marked clouding and a heavy viscid growth in the bottom. Tests for nitrite on the tenth day with starch water, potassium iodide, sulphuric acid gave a deep blue color, indicating the presence of nitrites (uninoculated tubes when tested gave no color).

Hydrogen sulphide production.—Tests with paper saturated with lead acetate hung over nutrient broth and over broth plus potato starch showed no signs of hydrogen sulphide production.

Ammonia production.—Tests with filter paper saturated with Nessler's reagent which was suspended over cultures in nutrient broth showed a reddish brown color, rapidly developing on the paper upon heating the solution, hence, that ammonia was produced.

Gas production.—One per cent of the following substances were used in nutrient broth kept at about 25° C. in fermentation tubes: dextrose, galactose, mannite, lactose, maltose, saccharose, inulin, and glycerin. Growth was very good in all and was sharply limited to the medium contained in the open arm, medium not

being agitated (see pl. 29, fig. 1). No gas was produced in the closed arm in any of the substances listed in contrast to *Bacillus Coli* which showed abundant gas in a number of the solutions. This does not mean that no gas was produced; it has already been shown that ammonia was produced in nutrient broth, but that because of the growth being limited to the open arm, any gas which was produced, and which in this organism must not be noticeable, passed off into the atmosphere through the open arm. However, no carbon-dioxide or hydrogen has ever been collected and it is not likely that they were formed in any appreciable quantity in this organism since it is not an acid producer.

Acid production.—Various experiments indicate that this organism does not produce acid in any of the ordinary media. It has already been noted that in acid broths the medium changes toward neutrality or becomes alkaline and that litmus milk becomes blue. Likewise, in the presence of carbohydrates there is no acid production at any time during the growth period. The following experiments illustrate this. Litmus agars containing no other nutrients than 1 per cent of the following carbohydrates remained blue for 2 months, showing no pinkish tinge at any time: dextrose, galactose, mannite, lactose, saccharose, raffinose, and glycerin. Nutrient agar with brom cresolpurple as indicator containing 1 per cent of the following: dextrose, galactose, lactose, and saccharose showed no trace of yellow in 10 days' growth. Lactose agar stabs with Andrade-Penny's indicator (Holman, II, '14) showed no color, in contrast to *Bacillus Coli* which developed a conspicuous pink color in 48 hours. Instead of producing acid this organism produced alkali in the presence of carbohydrates as is shown in the following table. The media consisted of nutrient broth plus 1 per cent of each of the carbohydrates listed.

TABLE VIII

Type of carbohydrate	Original P_H	P_H at end of 5 days	P_H at end of 10 days
Dextrose	7.2	7.2	7.3
Levulose	7.2	7.2	7.4
Mannite	7.2	7.4	7.4
Lactose	7.2	8.0	8.2
Maltose	7.2	8.0	8.0
Saccharose	7.2	8.0	8.2
Glycerin	7.2	7.2	7.2
Broth (without carbohydrate)	7.2	8.0	8.0

Growth was good in all and exceptionally heavy in dextrose and levulose broth. In every case except glycerin the medium was actually rendered more alkaline instead of acid. Does this mean that the foxtail organism does not utilize carbohydrates? If the production of acid and gas was taken as the only indication of carbohydrate utilization (as some investigators seem to believe) the question would be answered in the negative; yet in the case of the foxtail organism there is evidence to indicate that carbohydrates were used without the production of acid or gas (ammonia production resulted from protein decomposition). It is well known that carbohydrate utilization in complex and in simple organisms commonly results in the production of acid and of gas, but it is also known that certain organisms, such as yeasts, decompose carbohydrates and instead of yielding acid they produce alcohol. There are also definite cases on record where carbohydrates are shown to have been used and alkali produced. Thus Miss Karrer (II, '21, p. 78) states: " . . . . the reaction of all the culture solutions with starch as the source of energy was changed during the growth of the fungus (*Fusarium* sp.), this shift being toward increased alkalinity." She presents numerous curves which show the amounts of starch utilized in nutrient media which were acid at the beginning of the experiment and which developed alkali as growth took place. It is to be noted further that in the nutrient media she employed there was no organic nitrogen.

It is not intended to go into a lengthy discussion of acid and alkali production in relation to carbohydrates, how carbohydrates in the presence of nitrogenous food may first be utilized and thus exercise a "sparing" action on proteins, or how acid and alkali may be formed simultaneously, or how a preponderance of alkali may be formed either because of a preferential utilization of acid radicles or because alkali-yielding substances, such as proteins, are utilized to a greater extent. Considerable work has been done on the subject and much remains to be elucidated. Briefly summarized, the following experiments clearly indicate that carbohydrates are utilized by the foxtail organism; first, the marked diastatic action on starch in various media; second, the good growth obtained on media containing nothing but potato cylinders; third, the slight growth obtained in aqueous solutions containing only 1 per cent of each of these sugars, dextrose, galactose, mannite, and saccharose; fourth, the increased

growth in solutions containing sugar over those in which it is absent, in the amino acid series which was previously presented.

Hydrogen-ion concentration in relation to growth.—It has already been reported that the concentration of hydrogen ions plays an important part in the inhibition or enhancement of growth of the foxtail organism. In addition to the experiment on acid broths, nutrient broth was rendered acid or alkali by adding hydrochloric acid and sodium hydroxide aseptically after the broth had been sterilized. The following series was used: P_H 4.8, 5.0, 6.6, 7.2, 7.4, 7.6, 8.5, 8.6, and 9.8. There was good growth in P_H 6.6, 7.2, 7.4, and 7.6, and no growth in P_H 4.8, 5.0, 8.5, 8.6, and 9.8. This series in combination with the other studies indicate that the optimum reaction lies between P_H 6.0 and P_H 8.0, that the lower limiting reaction for growth is around P_H 5.0, varying somewhat with different media, and that the upper limit for growth to occur is somewhat below P_H 8.5.

NUTRIENTS IN RELATION TO PRECIPITATE PRODUCTION

Production of a colorless zone followed by a white discoloration has already been reported on nutrient agar and on whey agar when these gave a slightly acid reaction. It has also been reported that no precipitate was obtained on nutrient gelatin. In an effort to determine which material in the media contained the ingredient which gave rise to the precipitate a number of experiments were tried. Beginning with agar an attempt was made to substitute other plant materials for the algal product and the gums arabic and tragacanth were tried without success. The first of these when dissolved in water does not give a stiff medium even at very high concentrations, and the second is extremely difficult to dissolve in water. Attempts were then made to thoroughly wash the agar according to the method used by Ayers, Mudge, and Rupp (II, '20). These authors found that unwashed agar contained various calcium and magnesium salts as well as proteins and that by a thorough washing considerable part of these impurities were removed. Shredded agar was used, and after washing the nutrients peptone and beef extract were added in the usual amounts; part of the medium was allowed to remain slightly acid, P_H 6.6, and part was rendered slightly alkaline with sodium hydroxide, P_H 7.2. Good growth was obtained on both, and while no precipitate was obtained in the alkaline medium the characteristic white discoloration occurred on the

acid medium, indicating that impurities contained in the agar were probably not responsible for the formation of precipitate. As agar itself is not ordinarily considered a food, it seems reasonable to conclude that agar was not responsible for the white precipitate.

Water was the next ingredient investigated. Previous tests having indicated that a medium containing tap water, when slightly acid in reaction, gave a heavier precipitate than distilled water, tap water was used. Tap water was therefore treated with strong hydrochloric acid in order to remove carbonates, and boiled for several hours. It was then incorporated into nutrient agar, and part was rendered alkaline, P_H 7.2, and another part acid, P_H 6.6; nutrient agar containing untreated tap water and also 1 part made alkaline and another acid were run at the same time as checks. Growth on the alkaline medium containing treated water was as good as on the medium containing untreated water, but the medium testing P_H 6.6 with treated water did not give as good growth as the slightly alkaline medium. White precipitate occurred in the acid media, both with treated and untreated water. This indicates that water does not influence the production of precipitate. (Chemical tests made of the water at Fayetteville, Ark., by the department of chemistry of the University of Arkansas indicate that of the materials found in the local tap water, carbonates made up by far the largest proportion, other substances being but slightly more than a trace.)

Substitutions were then attempted for peptone; the media used were (1) 1 per cent dextrose-beef extract agar; (2) 1 per cent lactose-beef extract agar; (3) 1 per cent dextrose, and .1 per cent tyrosine-beef extract agar. In all of these the ordinary 0.3 per cent beef extract was used, each divided into 2 parts, 1 rendered slightly acid and the other slightly alkaline. Growth in the first 2 was not as good as in media containing peptone, but the 1 containing tyrosine gave a growth which appeared fully as good as on ordinary nutrient agar. (Davis (II, '17) has found that the value of peptone is governed by the amino acids present and he has concluded that tyrosine and tryptophane are important constituents of satisfactory peptone.) On each of the 3 media listed, precipitate was obtained in the part testing slightly acid. This clearly indicates that the commercial peptone is not responsible for the white precipitate.

Beef extract is the remaining nutrient to be considered. Media containing but 1 per cent dextrose and 0.1 per cent tyrosine in agar were tried, and no precipitate was obtained either in acid or in alkaline media. Growth in these was not good, but this is not the factor in preventing precipitate production since the precipitate was produced in 1 per cent dextrose plus beef extract even though growth was poor. It may then be concluded that beef extract is the probable source of the white precipitate, and while no similar study has been made on whey agar it is quite probable that whey is the source of the precipitate in this latter medium.

CHEMICAL NATURE OF THE PRECIPITATE

The precipitate was soluble in all of the acids tried, including the following: glacial acetic, chromic, citric, hydrochloric, nitric, sulphuric, lactic, picric, and warm boric; it was insoluble in warm or cold water or organic solvents, including methyl, ethyl, and butyl alcohol, glycerin, acetone, ether, petroleum ether, chloroform, oil of turpentine, benzole, xylol, tuluol, benzine, carbon bisulphide, carbon tetrachloride, potassium permanganate, hydrogen peroxide, and ammonium peroxide. This indicates that the precipitate is an inorganic salt. Tests were made for carbonates and phosphates with the result that posphates were clearly detected. Since the precipitate, while conspicuous, may be had in comparatively very small amounts it is rather difficult to test. The procedure was as follows: With a platinum loop the bacterial smear was carefully removed (all tests were made on agar slants); the tube was washed several times with distilled water and care was taken to see that all bacterial growth, where this was a possible factor, as well as particles of medium, were removed. One per cent solution of nitric acid was then used to dissolve the precipitate, the fluid decanted, filtered through fine filter-paper, and tested with ammonium molybdate reagent (see Treadwell's 'Qualitative Analysis'). Tubes containing the same media but without showing any precipitate, the ones reacting alkaline, were treated in exactly similar manner and run at the same time. Many such tests show that the precipitate, if not wholly, is in large part phosphate, as indicated by the yellow color, and precipitate developed in solutions coming from tubes which originally contained the white discoloration.

It is very difficult to obtain a test of any nutrient agar in which the yellow precipitate produced by ammonium molybdate

is entirely absent, since the addition of strong acid may not only disintegrate any bacteria which may be present but may also dissolve some of the nutrient medium. However, there is no difficulty in obtaining a marked quantitative difference of yellow precipitate when the same amount of reagents are used in tubes possessing the white precipitate as against tubes which do not, those tubes containing the precipitate always giving a greater amount of yellow ammonium phosphomolybdate. In a number of tests, where the bacterial growth was removed *in toto*, often very difficult to do without breaking up the medium, and where the acid was allowed to act only a short time, no yellow precipitate occurred in tubes which did not possess the white precipitate.

It seems to be well established that beef extract contains phosphates, the following statement in Eyre's 'Bacteriological Technique,' p. 128, indicating this: "Meat extract . . . is acid in its reaction owing to the presence of acid phosphates . . . ." The following appears to be a plausible explanation for the production of a colorless zone plus a white precipitate on acid media. It has been shown that the foxtail organism in its growth on various media, including nutrient agar, produces alkali. The alkali acts on the acid phosphates and causes them to precipitate out of solution. (It is well known that various acid phosphates are precipitated out of solution when alkali is added.) Immediately around the organism the phosphate is probably used up as growth proceeds, while the phosphate beyond a certain distance of the bacterial growth, not having been used, is acted on by the alkali which diffuses from the region of growth and is precipitated out of solution. There is also the possibility of an action by a carbon dioxide gradient which, being greatest in the region immediately surrounding the colony, might prevent precipitation by the acid reaction. No precipitate is produced on alkaline media, probably because the substances from which the white precipitate is derived were largely precipitated out when the medium was rendered alkaline. This seems to be in keeping with Eyre's observation (p. 150). In giving directions for making nutrient agar he recommends the addition of sodium hydroxide until a reaction of +10 is obtained (this often is equivalent to P_H 7.0 or P_H 7.2 as previously shown) and further recommends the following as the next step after the addition of al-

kali. "Replace in the steamer for twenty minutes (to complete the precipitation of the phosphates, etc.)."

Which phosphates are involved in this precipitate has not been determined. In experimenting with anhydrous disodium glycerophosphate Mellon and his associates (II, '21) decided that this substance acts as a solvent for calcium and magnesium salts. Accordingly, it was incorporated into nutrient agar in the proportion they recommend. The medium was divided into several parts, some being rendered acid and some alkaline by the addition of hydrochloric acid or by sodium hydroxide giving the following reactions: P_H 6.0, 6.3, 6.6, 6.8, and 7.4. Growth on this medium as a whole is somewhat better than on ordinary nutrient agar. It makes a clear medium although a dense precipitate settles at the bottom of the tubes after sterilization. No white precipitate was produced on either the acid or alkaline side. It is of course difficult to say how this is brought about, whether the presence of this salt prevents precipitation by its solvent action on calcium and magnesium salts, or because this salt when added to peptone-beef extract agar precipitates out materials which would otherwise enter into the production of white precipitate, or because of its buffer action in preventing a change in the hydrogen-ion concentration. At any rate, it is quite probable that the white precipitate is in the nature of a complex phosphate and not a simple calcium or magnesium salt.

PHYSIOLOGICAL REACTIONS

Effect of temperature on growth.—The medium used was nutrient broth testing P_H 6.8, care being taken to add approximately the same amount of inoculum, 0.1 cc. of 48-hour broth culture, to each 10 cc. of medium. The organism was subjected to the following temperatures (degrees centigrade): 10, 14, 20, 25, 30, 35, 40°. With the exception of the 30° incubator which maintained very nearly a constant temperature, there was some variation in all of the others amounting to 1–2 degrees, so that the temperatures given are not absolute. In 24 hours there was a heavy clouding at 34–35°, almost as heavy at 30°, noticeably less at 25°, only a slight growth in the upper fourth of the broth at 20°, no visible growth at 14°, and none at 10°. In 48 hours a slight growth was visible at 14°. At the end of a week there was a faint clouding at 10,°, more noticeable clouding at 14°, and beginning with 20° growth was very marked up to 35°, with

none at 40°. Growth appeared first and was heaviest at 30–35°, which may be regarded as the optimum zone. The minimum zone has not been determined but it is probably around 0°, while the maximum is around 40°. Death occurred at 41 to 43°. It is thus seen that the optimum, a rather high temperature, is quite close to the maximum which in turn is close to the thermal death point.

Effect of drying.—Bacterial smears on sterile cover glasses were kept dry for 1 hour, 5 hours, 48 hours, and 3 days, at 25° C. When these glasses were dropped into broth growth occurred in all except the one kept dry for 3 days. One would conclude then from this experiment that the foxtail organism is sensitive to desiccation. The following data indicate that such a conclusion is quite false. Diseased material collected July 30, 1921, and kept in a dry condition in the laboratory at about 25° C. until March 24, 1922, a period of about 7 months, was surface sterilized in the ordinary manner, macerated in sterile water, and sprayed on oat seedlings, giving abundant infections, while a check pot sprayed with sterile water showed none. The experiment was duplicated with the same results.

The writer is convinced that the effect of drying cannot be measured merely by smears on glass, and taken by themselves such tests are apt to lead to erroneous conclusions. The reason for this is apparent, bacteria within infected host tissue being of course more or less closely associated with cellular matter. The action of plant colloids in taking up and holding water has been carefully investigated (see MacDougal, Carnegie Inst. Publ. 297) so that the colloids in association with bacteria must be considered in any water relationships. It thus appears that the foxtail organism is resistant to drying.

Effect of freezing.—Using 48-hour broth cultures, 0.2 cc. was inoculated in tubes containing 10 cc. of broth. Two tubes were placed into a freezing, brine-ice mixture, and 2 into an incubator at 35° C. After 2 hours the 2 tubes, which had remained in the form of solid frozen masses for more than 1½ hours, were removed from the freezing mixture, thawed out, and poured plates made from calculated dilutions. Check tubes kept in the incubator for the same length of time were treated in the same way. Using equal amounts of inoculum no noticeable difference in the number of colonies which developed was obtained. The experi-

ment indicates that the foxtail organism is not readily killed by freezing and thawing.

Effect of sunlight.—Moderately thick sowings of a 48-hour broth culture were made on nutrient agar-poured plates. One-half of each plate was covered with black paper and the plates, resting on ice, were exposed to a bright December sun for 5, 10, 15, and 20 minutes, triplicates being used for each time period. They were then incubated at about 32° C. No difference in number of colonies could be detected for any of the periods in the exposed as against the covered half. The results were rather unexpected since bacterial pathogens are often described as sensitive to sunlight, certainly within the range employed, 5 to 15 minutes being sufficient to kill or very much retard colony development in a large number of forms. The experiment was therefore duplicated in May and exposures of 15, 30, and 45 minutes made to a bright sun. There was hardly more than a 10 per cent reduction in the number of colonies on plates exposed 30 and 45 minutes as compared to those exposed 15 minutes, the difference being within the limits of experimental error. The number of colonies (about 150) which developed after 45 minutes on the exposed half as compared to the covered half was hardly different. The organism does not appear to be very sensitive to sunlight.

Overwintering.—Experiments on the effect of desiccation and freezing indicate that the organism has no difficulty in overwintering. Unfortunately diseased material which had been placed out of doors in the fall to be tested the following spring was destroyed so that there is no direct evidence for overwintering. Field observations as well as laboratory studies indicate that overwintering is readily accomplished. The writer has already recorded the presence of the disease for 4 successive seasons on the same field. The organism may be carried over winter either in diseased glumes, or possibly in the soil in diseased leaves.

Vitality on culture media.—If the substratum is not permitted to dry down, the foxtail organism will continue to live for a long time. In liquid media, such as nutrient broth and milk, growth may be obtained after a period of 6 months, and infections are readily produced from broth cultures kept 4 months at about 25° C. However, when the organism growing on nutrient agar slants is kept in the ice-box for 9 months it loses its viability.

Group number.—According to the most recent chart adopted by the Society of American Bacteriologists (Conn, et al, II, '20), the foxtail organism has the following index number: 5322-31220-1333.

Technical Description

Pseudomonas alboprecipitans,[1] n. sp.[2]

Narrow rods with rounded ends, solitary or in pairs; average measurement of single rods 0.6 by 1.8 μ, motile by a single polar flagellum; no spores, zoogloea or irregular forms; capsules present; strict aerobe; surface colonies on nutrient agar white, round, somewhat raised, smooth, amorphous, sticky, margins entire, surrounded by areas followed by a white precipitate on media testing acid, as P_H 6.6; nitrates reduced to nitrites; ammonia produced; indol and hydrogen sulphide not produced; no acid or gas produced in the presence or absence of carbohydrates; diastatic action strong; no growth in Cohn's solution but growth in Uschinsky's and Fermi's solutions is fair; minimum temperature about 0° C., optimum between 30 and 35°, maximum about 40°, thermal death point 41–43°; vitality on culture media comparatively long; not sensitive to drying or freezing; not very sensitive to sunlight; Gram-negative, not acid fast. Pathogenic to *Chaetochloa lutescens, C. geniculata, C. italica, Avena sativa, Holcus Sorghum, H. Sorghum sudanensis, Hordeum vulgare, Secale cereale, Triticum sativum,* and *Zea Mays.*

Summary

The bacterial disease here described is common on yellow foxtail in Arkansas. No concerted effort has been made to discover the disease on other grasses but artificial inoculations show that the pathogen is infectious on wheat, oats, rye, barley, corn, Sudan grass, millet, and perennial foxtail.

[1]According to the classification suggested by Smith (II, '05, p. 171) the combination would be *Bacterium alboprecipitans* n. sp.

[2]**Pseudomonas alboprecipitans,** sp. nov., aerobus; baculis asporis cylindricis singulis vel binatis apicibus utrinque rotundatis flagello uno polare mobile, baculis solitariis 0.6×1.8 *μ*.

Coloniae in agar-agar rotundatae albae leves, marginibus plenis; in culturis acidi minimi zonae hyalinae factae sunt secutae a precipito albo. Gelatina non liquefacit. Acidum et gas non efficiuntur.

Habitat in foliis vivis *Chaetochloae lutescentis, C. italicae, C. geniculatae, Tritici vulgaris, Secalis cerealis, Avenae sativae, Hordei vulgaris, Zeae Mays, Holci Sorghi.*

Arkansas, Amer. bor.

A large number of varieties of various cereals are subject to attack. Artificial inoculations also indicate that the organism is capable of doing serious damage, particularly to seedlings of oats and barley.

Lesions on foxtail appear as light brown or dark brown spots and streaks of no definite size or shape and may occur on any part above ground, but are most often found on blades and sheaths.

Attacks on other hosts vary from light yellow indefinite areas, often with a reddish tinge in the case of oats, to grayish-green, markedly withered areas.

The disease appears to be different from any other known bacterial disease of grasses.

Attacked tissues teem with bacteria which discolor, disintegrate and finally kill the invaded tissue. Entrance to the host is by means of stomata and water pores.

The organism is a single-flagellate rod, white in culture, with colonies surrounded by a characteristic colorless area followed by a white precipitate on slightly acid media. It is described as *Pseudomonas alboprecipitans* n. sp.

The meaning of hydrogen-ion concentration, its relation to titratable acidity, methods of measuring it, and the necessity of utilizing it in the study of bacterial pathogens are discussed. Comparisons are given between Fuller's scale and P_H values.

Numerous cultural reactions are presented, including a method for definitely controlling precipitate production by means of varying the hydrogen-ion concentration; the relationship of various organic anions to growth, comparison between cotton and glass wool as filtering agents, the use of lima bean agar in bacterial studies, and a study of several amino acids in relation to growth of bacteria are also discussed.

It is found that beef extract is the probable source of the white precipitate in media which contain the extract and that this precipitate is a phosphate.

Part of the work presented in this paper was prosecuted as an Adams project at the Agricultural Experiment Station of the University of Arkansas. Special thanks are due to Dean Bradford Knapp for facilities made available and to Dr. J. A. Elliott who made the colored drawings and who gave kindly assistance and encouragement in the prosecution of the work. The work was continued at the Missouri Botanical Garden under the guidance

of Dr. B. M. Duggar, and I am greatly indebted to him for very helpful suggestions and for critical advice. Thanks are also due to Dr. George T. Moore for the privileges and facilities of the Missouri Botanical Garden.

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Explanation of Plate

PLATE 23

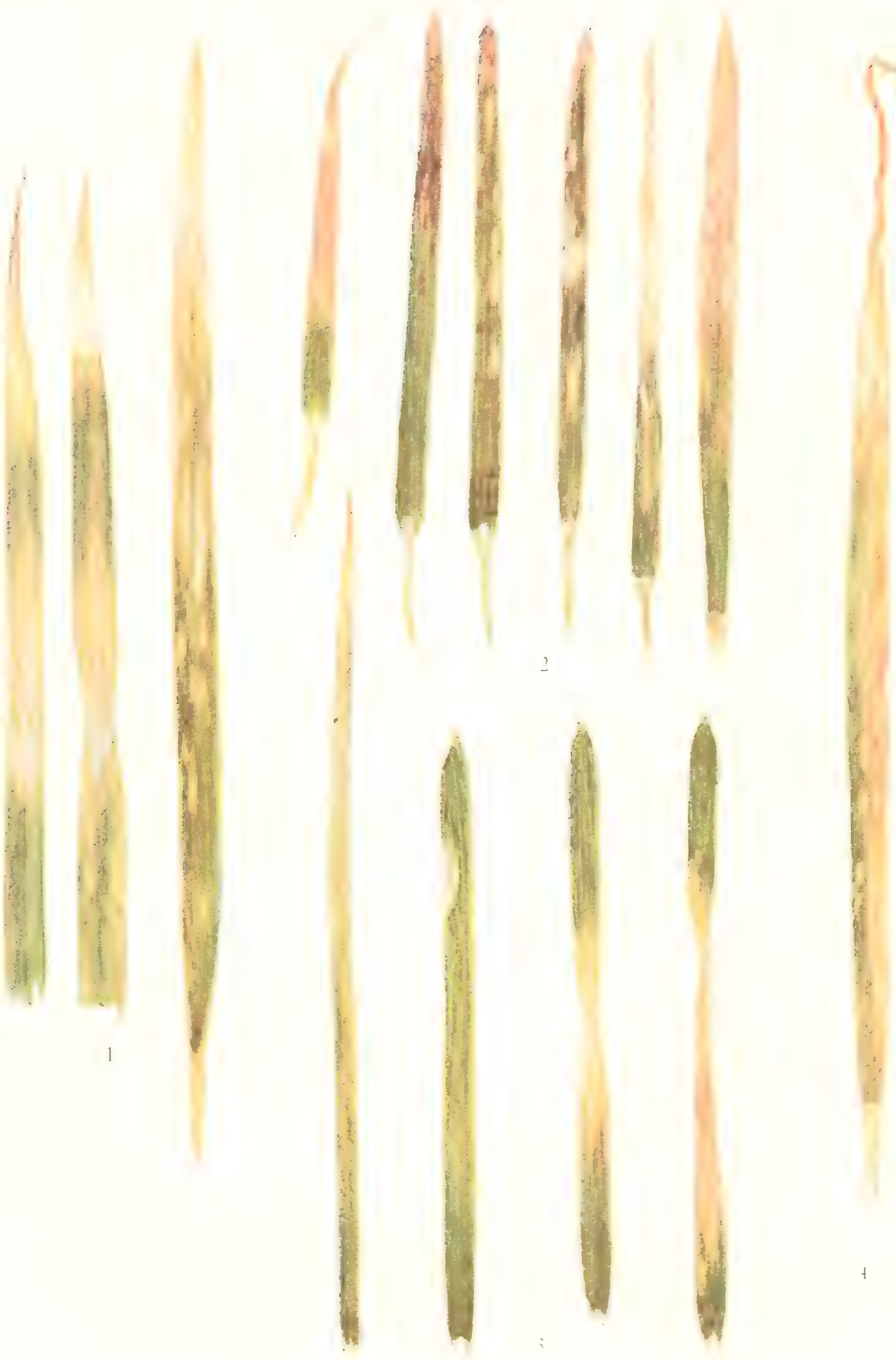
Fig. 1. Natural infections on foxtail (3 leaves).
Fig. 2. Artificial infections on foxtail (2 leaves).
Fig. 3. Artificial infections on sorghum, variety "Amber Cane."
Fig. 4. Artificial infections on *Chaetochloa geniculata*.
Fig. 5. Artificial infections on corn.

ROSEN—A BACTERIAL DISEASE OF FOXTAIL

Explanation of Plate

PLATE 24

Fig. 1. Artificial infections on barley (3 leaves).
Fig. 2. Artificial infections on oats (6 leaves).
Fig. 3. Artificial infections on wheat (4 leaves).
Fig. 4. Artificial infections on rye.



ROSEN—A BACTERIAL DISEASE OF FOXTAIL

Explanation of Plate

PLATE 25

Upper figures represent various types of natural infections on foxtail, including blackish streaks and blotches, small dark brown, oval-shaped or roundish spots with light centers and withered light brown tips.

Lower right-hand figures represent artificial infections; left-hand figure a normal head of foxtail (*Chaetochloa lutescens*).

ROSEN—A BACTERIAL DISEASE OF FOXTAIL

Explanation of Plate

PLATE 26

Fig. 1. Pot on the left—dead oat plants 4 days after inoculation with the foxtail organism; on the right—check plants of the same age sprayed with sterile water.

Fig. 2. On the right—badly diseased barley seedlings 4 days after inoculation; on the left—barley plants of the same age sprayed with sterile water.

ROSEN—A BACTERIAL DISEASE OF FOXTAIL

Explanation of Plate

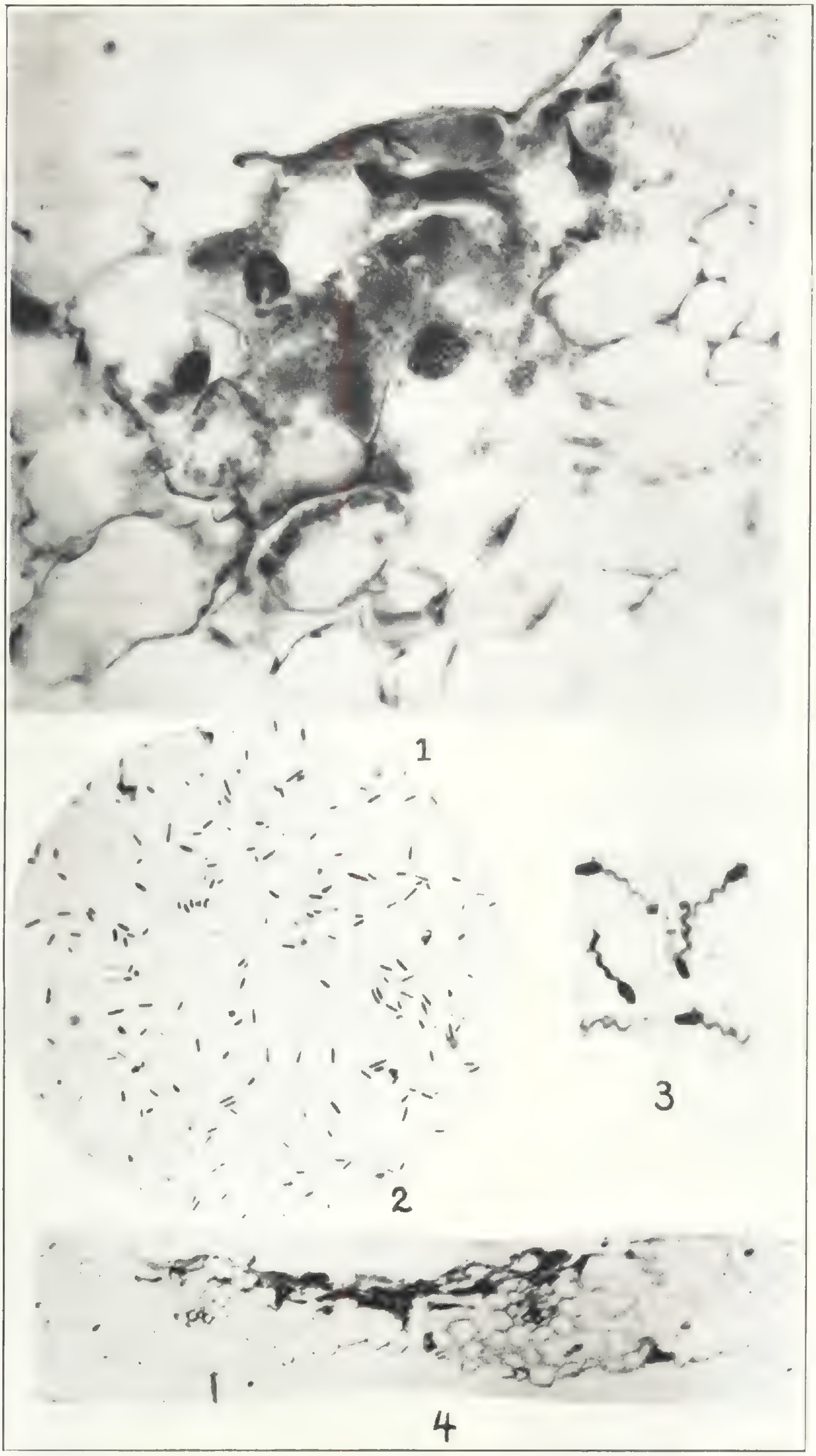
PLATE 27

Fig. 1. Section through a diseased spot of an oat leaf artificially infected, showing portion of a substomatal cavity as well as neighboring cells and intercellular spaces filled with bacteria. Magnified about 950 times.

Fig. 2. Foxtail organism stained with carbol fuchsin, obtained from young agar slant culture. Magnified about 1000 times.

Fig. 3. Foxtail organism stained with Van Ermengem's flagella stain. Magnified about 1200 times. Bodies of the organisms, except the lower ones to the left, retouched; all flagella remain untouched.

Fig. 4. Cross-section of a diseased oat spot showing discoloration and collapse of attacked cells. Magnified about 450 times.



ROSEN—A BACTERIAL DISEASE OF FOXTAIL

Explanation of Plate

PLATE 28

Fig. 1. Four-day colonies on nutrient agar testing P_H 6.6, showing colorless zone surrounded by a marked white precipitate.

Fig. 2. Same as fig. 1, showing a thickly sown plate with a coalescing and spreading grayish sheet of colonies deeply imbedded and growing next to the glass.

Fig. 3. Ten-day slant of nutrient agar testing P_H 6.4 showing colorless zone surrounded by a marked white precipitate.

1

2

3

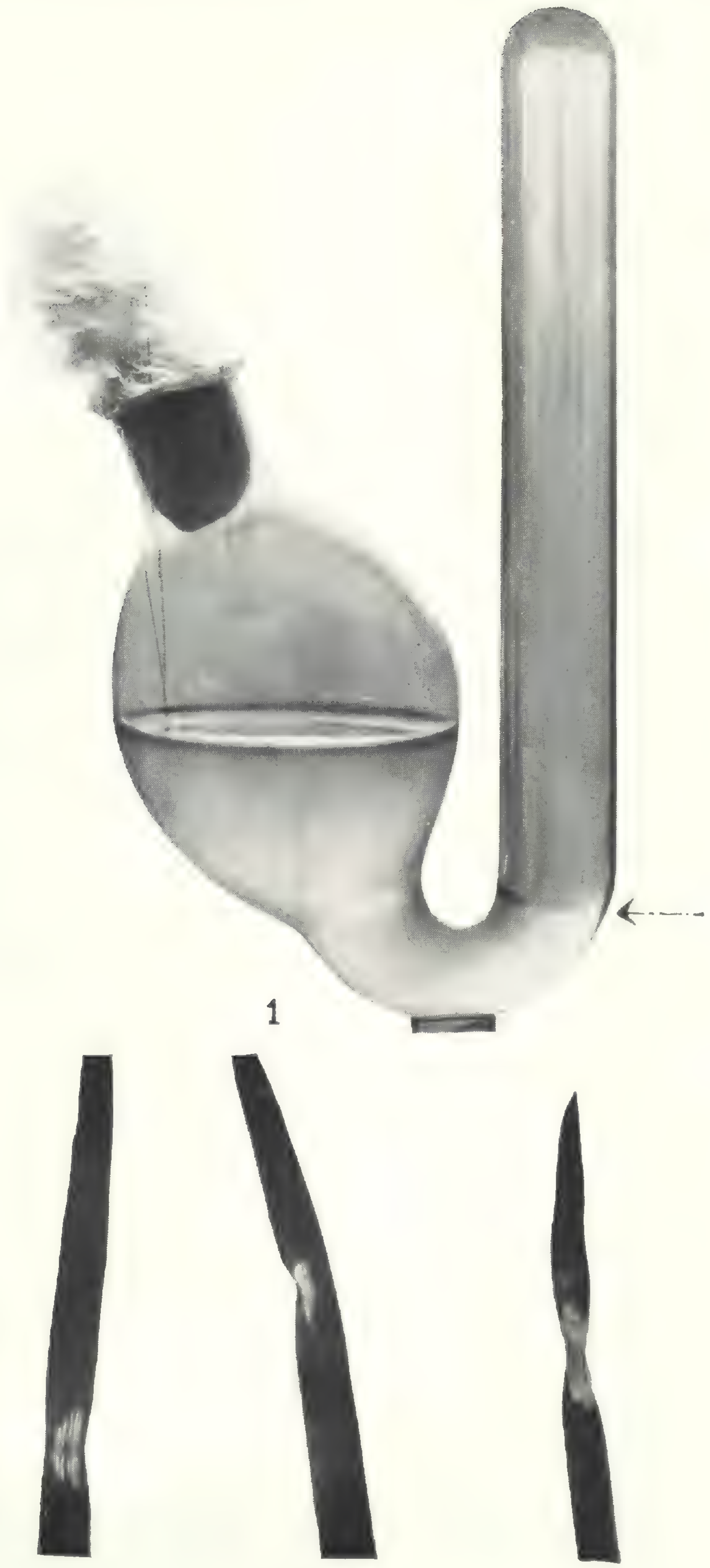
ROSEN—A BACTERIAL DISEASE OF FOXTAIL

Explanation of Plate

PLATE 29

Fig. 1. Dense clouding in open arm in 1 per cent mannite-nutrient broth with no growth above the arrow point, and no gas.

Fig. 2. Wheat leaves inoculated at infected points with a pure culture of the foxtail organism, by means of a sterilized platinum loop.



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2

ROSEN—A BACTERIAL DISEASE OF FOXTAIL

THE TOXIC PROPERTY OF SULPHUR[1]

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Introduction

Since the introduction of spraying for the control of parasitic fungi there has been developed a large number of fungicidal mixtures. Some have proved effective for the control of one organism and some for another, none of them having universal fungicidal value. Because of its abundance, low cost, and its effectiveness under certain conditions, sulphur has been employed in many of these mixtures. The fact that it has toxic or fungicidal properties has been conclusively demonstrated. In this work, an attempt has been made to determine if possible the exact nature of this fungicidal property, that is, to determine or evaluate the chemical compound or compounds in which this toxic property is resident, at the same time to relate this toxic property to conditions under which it may be consistently manifest, thus warranting its general use as a fungicide.

The use of sulphur as a fungicide probably antedates that of all other substances. The chemical and physical properties of sulphur, especially its existence in so many forms, have led to its employment as a fungicide in a variety of ways. Regardless of the form in which it is employed, whether as a compound or as uncombined sulphur, there seem to be necessary certain chemical or physical changes before its toxic properties are exhibited. Toxicity has been attributed to many of the forms, for example, to such products of combined sulphur as various sulphides, thiosulphates, sulphur dioxide, sulphuric and sulphurous acids, and also to uncombined sulphur as flowers, or even as sulphur in a more finely divided state, that is, as colloidal sulphur. However, there seems to be no tangible evidence in the past work that toxic properties can be attributed directly to any one of these forms, the presence of which might thus determine its value as a fungicide. The exact state or states in which sulphur is toxic was left as a matter of considerable speculation.

[1] An investigation carried out at the Missouri Botanical Garden in the Graduate Laboratory of the Henry Shaw School of Botany of Washington University, and submitted as a thesis in partial fulfillment of the requirements for the degree of doctor of philosophy in the Henry Shaw School of Botany of Washington University.

[2] A fellowship established by the Crop Protection Institute for the investigation of sulphur as a fungicide.

History

The generally employed sulphur sprays, namely, flowers of sulphur and the various sulphide compounds, have been only partially effective in controlling fungous diseases. It will not be necessary in this paper to go into a historical discussion of the effectiveness of these sprays, as such discussions are reported frequently by agricultural experiment stations and horticultural societies in bulletins and spray calendars and my own conception of the practical problems involved will be stated below. This work has to do largely with the fungicidal properties of sulphur.

The toxicity of the flowers of sulphur has been attributed to several compounds, of which hydrogen sulphide, sulphur dioxide, sulphurous and sulphuric acids, and volatile sulphur are more often given. Pollacci ('07) believes that sulphur is transformed into sulphuretted hydrogen, the vapors of which have a very energetic action on the fungi. This view, however, has received but little support and has been proved untenable by Bourcart ('13). He was unable to collect any of this gas on passing air from sulphur through solutions suitable for retaining the gas. Foreman ('10) could obtain no inhibition of germination with spores of *Botrytis cinerea,* using a saturated solution of sulphuretted hydrogen. Similar results were obtained by Barker, Gimingham, and Wiltshire ('20). It is at present generally accepted that hydrogen sulphide is not a factor as a fungicidal property of sulphur.

The view that the toxic action of sulphur is due to sulphur dioxide has received considerable support. Sostegni and Mori ('90), Blodgett ('13), Butler ('17), and Kuhl ('21) conclude that the toxic property of sulphur is due to this gas. They believe that the gas is slowly produced by the oxidation of the sulphur. In the papers cited there is little substantiating experimental evidence, other than the fact that the toxic compound is volatile. Contrary views are held by Bourcart ('13) who states that "Sulphurous acid must not be dreamt of; 1/40,000 of this acid in the air would burn the leaves." In a series of experiments he could not collect any sulphur dioxide evolving from sulphur at temperatures up to 50° C. Barker, Gimingham, and Wiltshire ('20) obtained good germination of spores of *Nectria ditissima* in a 1:100 solution of sulphur dioxide. Closed-ring experiments, however, gave limits of .005 per cent and .0005 per cent for the germination of spores of *Sclerotinia fructigena, Fusicladium den-*

driticum, F. Pyrinum, Botrytis cinerea, and *Nectria ditissima.* They conclude that sulphur dioxide cannot be a factor.

Marcille ('11) attributed the toxic property of sulphur to sulphur trioxide and sulphuric acid in the control of grape mildew. A similar conclusion was arrived at by Moissan ('04) who was able to obtain this gas from the spontaneous oxidation of different kinds of sulphur at ordinary temperatures. As far as the author is aware, these results have never been confirmed, and Bourcart ('13) and Barker, Gimingham, and Wiltshire ('20) proved on the contrary that sulphur trioxide and sulphuric acid do not contribute to the fungicidal property of sulphur.

That sulphur is toxic because of its volatilization as such is probably the view most commonly held at the present time. The fact that spores are inhibited in germination when not in direct contact with the sulphur particle has been frequently demonstrated. Smith ('06), working with asparagus rust, concluded that sulphur acts by its fumes but that the sulphur must be uniformly distributed to be effective in controlling the disease. He found that the disease was best controlled in air pockets which aided in preventing a too rapid spreading and dilution of the fumes. Similar views are held by Mares and Mohr (see Bourcart, '13), Bioletti ('07), Bourcart ('13), Barker, Gimingham, and Wiltshire ('20), Doran ('22), and others.

The conditions under which sulphur is volatile or under which volatile substances are formed from sulphur have been investigated by Marcille ('11), Bourcart ('13), Blodgett ('13), Kuhl ('21), and Doran ('17, '22), with the following general conclusions: (1) a certain temperature must be maintained, usually above 25° C; (2) oxygen is necessary; (3) sunlight is a possible factor; (4) the influence of the leaves and spores is considered by some a factor. These conclusions were arrived at by the use of flowers of sulphur.

The toxicity of other forms, such as finely divided sulphur and the various sulphides, has been investigated by a number of workers. Doran ('22) found that Schloesing's precipitated sulphur[1] was more effective in killing spores of *Venturia inaequalis* than any of the finely divided sulphurs used. Atomic sulphur[2] has been reported effective.

[1] Manufactured by Usines Schloesing Freres et Cie., of Marseille, France.
[2] Prepared by the General Chemical Co., New York and Baltimore.

Since the origination of lime sulphur as an orchard spray by M. F. Dusey of Fresno, California, in 1886, there has been a number of studies made on its effectiveness as a spray and on its chemical composition. The first of these of importance was by Thatcher ('06). He found that lime sulphur contained for the most part calcium polysulphides, calcium thiosulphate, and small quantities of sulphites and sulphates. Haywood ('09), using the same methods, obtained similar results. When he dried the mixture the polysulphides disappeared and increasing amounts of precipitated sulphur were formed. He attributed the fungicidal value of lime sulphur particularly to the thiosulphates and possibly to a combined or a summation of the toxic properties of all the compounds formed exclusive of sulphur.

Van Slyke, Bosworth, and Hedges ('10) made some chemical determinations of lime sulphur when the ingredients were varied. They came to the conclusion that a mixture containing a high proportion of sulphur had the largest amount of calcium pentasulphides and a greater fungicidal value. They proposed the following formula: 80 lbs. sulphur, 36 lbs. calcium oxide, and 50 gallons water. This formula is the one in general use at the present time. Their chemical determinations gave about the same results as those obtained by Haywood ('09). Ruth ('13), in a study of lime sulphur and lead arsenate mixtures, found that no arsenic sulphide was formed. The proportion of thiosulphates and sulphites was increased in this mixture, and he attributed the increased effectiveness of the spray to the presence of additional quantities of these compounds. There was no experimental evidence for this, and his chemical determinations did not show the presence of any particular toxic compound. Harris ('11) made chemical determinations of lime sulphur mixtures and found about the same amounts of sulphides, sulphites, etc., as Haywood. He also stated that filtering was unnecessary. Official methods for the determination of the compounds formed in lime sulphur are given by Roark ('20) and Winter ('20).

The above studies on lime sulphur have had to do with freshly prepared mixtures. Vermorel and Dantony ('19) gave a number of reactions that probably took place in lime sulphur mixtures and the compounds formed when the mixture was aerated. They found that the polysulphides soon disappeared after the spray was applied. The calcium thiosulphates gradually decreased, and sulphites, sulphates, and free sulphur increased. Barker,

Gimingham, and Wiltshire ('20) concluded that calcium thiosulphate, hydrogen sulphide, and sulphur dioxide were all slightly toxic but not sufficiently so to account for the fungicidal value of lime sulphur. The calcium pentasulphides were toxic, but since they disappeared in a few hours the lasting toxicity of lime sulphur could not be attributed to them. They concluded that the lasting toxic property must be due to precipitated sulphur. Doran ('22) also found that the sulphides decomposed very rapidly, especially when dried slowly.

Several other sulphide preparations have been employed as fungicides but have proved more or less ineffective as a lasting spray because their retention on the tree as sulphides is difficult to maintain. Their caustic nature frequently results in severe burning.

In testing the toxicity of sulphur and its compounds considerable confusion has developed owing to the variation in resistance of different species of fungi. Barker, Gimingham, and Wiltshire ('20) found that germination of the spores of *Sclerotinia fructigena* and *Phragmidium subcorticium* were entirely inhibited in a suspension of flowers of sulphur in Van Tieghem cells. Germination of *Fusicladium dendriticum* and *Cladosporium fulvum* were 50 per cent inhibited, while that of *Nectria ditissima, Botrytis cinerea,* and *Verticillium* sp. was not at all inhibited. When the flowers of sulphur was used Doran ('22) found that a much higher temperature was necessary for the killing of spores of *Botrytis cinerea* than for *Venturia inaequalis* and a higher temperature for the latter than for spores of *Sclerotinia cinerea.*

Experimental

Since most of the evidence listed in the foregoing references points to sulphur as being the toxic agent regardless of the sulphur mixtures used, it was first thought important to study the influence of the sulphur particle and molecule on the germination of spores. The Van Tieghem cell and the hanging-drop culture method, later slightly modified, were employed. The percentage of germination of the spores was used as an indication of toxicity. The organisms used were selected from the group of strict parasites most of which are of economic importance. It was also necessary to select those that sporulated readily. The following forms were used: *Colletotrichum Gossypii, Sclerotinia cinerea, Botrytis cinerea, Glomerella cingulata, Gloeosporium*

venetum, Macrosporium sarcinaeforme, Phomopsis Sojae, and *Actinomyces Scabies.* These organisms were grown on potato agar prepared according to the method of Duggar, Severy, and Schmitz ('17), and spores were taken from cultures 10–15 days old.

The culture solution used in the hanging drops and in which the sulphur particles were suspended was a slightly buffered mixture containing mannite, phosphoric acid, and sodium hydroxide. The solution was prepared according to the method of Karrer and Webb ('20), as follows: Stock solutions of M/5 mannite in M/10 phosphoric acid and M/5 mannite in M/5 sodium hydroxide were made. Equal quantities of the M/5 mannite-M/10 phosphoric acid were placed in each of 10 flasks and successively increasing proportions of M/5 mannite-M/5 sodium hydroxide were added. The flasks were plugged with cotton, sterilized at 15 lbs. pressure for 15 minutes, and allowed to stand for a few hours. Titrations made by the colorimetric method (Clark, '20) showed the mixtures to have the following range of hydrogen-ion concentrations: P_H 1.6, 2.4, 3.2, 4.2, 5.2, 5.8, 6.4, 6.8, 7.4, 8.4.

EXPERIMENT I. TOXICITY OF THE FLOWERS OF SULPHUR

Since sulphur in the form of flowers is insoluble in any solution that can be used for the growing of fungi, it was necessary to test its toxicity in the form of suspensions. Twenty test-tubes were provided with pipettes that extended through the cork stoppers and to the bottoms of the tubes. By this means drops could be transferred readily to the hanging-drop cells. These test-tubes constituted a duplicate series of 10 each, and 5 cc. of each of the slightly buffered solutions were added to the tubes so that each tube represented a particular hydrogen-ion concentration. To one series .5 gm. of flowers of sulphur was added to each tube.

The technique of the planting of the hanging-drop cultures was essentially the same as that used by Webb ('21) in his germination studies, and was as follows: Ground glass rings were cemented to glass slides by means of parawax and petrolatum. Two of these rings were placed on each slide, and 20 slides constituted a series for each organism. This gave duplicate cultures for each hydrogen-ion concentration. A few drops of the sulphur suspension to be tested for its toxicity were placed in the bottom of the two cells. Another drop was placed on a clean

sterile glass slide. A loop-full of spores was placed in this drop and the spores evenly distributed throughout the drop. By means of a small sterile glass rod a small portion of this drop was transferred to a clean sterile cover glass and the latter inverted over the glass cell. The cell was made air-tight by sealing with petrolatum. In like manner cultures were made representing each hydrogen-ion concentration both with and without sulphur. The series of hanging-drop cultures were then kept at room temperature. Examinations were made at the end of 16 and 24 hours.

After examining some of the preliminary cultures it was found that considerable irregularity in germination existed. Some types of spores would remain on the surface of the drops and often would not be in close proximity to the sulphur. Other types of spores were found to be in the center of the drops with the sulphur particles. Different-sized drops would often result in irregular germination in the control cultures. With some organisms the number of spores in the drop influenced the rate of germination. To eliminate such chance for error a definite spore suspension was made and the drop on the cover glass was spread over a much larger surface, giving it more the nature of a smear. In this way a more even distribution of both the spores and the sulphur particles was obtained. The results of the experiment are recorded in table 1 and figs. 1–4.

Sulphur in this form was found to be directly toxic to only two of the organisms used. In the other forms the spores were not only not inhibited from germinating but the germ tubes grew normally when in direct contact with the sulphur particles. It can only be concluded from these results that if the flowers of sulphur has a general fungicidal value it must be due to some change in the form of sulphur and that this change takes place under different conditions than were obtained in closed-ring Van Tieghem cells. Within the usual range for germination the hydrogen-ion concentration influenced the results but slightly.

EXPERIMENT 2. FINELY GROUND FLOWERS OF SULPHUR

Since the ordinary flowers of sulphur was toxic to two of the organisms, it was concluded that there was a toxic property present but in a very dilute form. If physical conditions influenced the production of this property it was thought that possibly a finely ground product might be more effective. To obtain sulphur in this state an electrically driven excentric mortar, as used for

crushing yeast cells, was employed. Eight gms. of flowers of sulphur were mixed with 3 gms. of diatomaceous earth (Kieselguhr), and the mixture ground for 14 hours. One-half gm. of this mixture was added to each test-tube containing the slightly buffered solution of the different hydrogen-ion concentrations and the toxicity determined as before. An attempt was made to grind the sulphur without the diatomaceous earth but the sulphur had a tendency to cake and did not grind well. Other substances are being tried with the hope of eliminating diatomaceous earth. Results of this experiment are given in table 1, figs. 1–4.

Sulphur in this state was found to be more toxic than the flowers of sulphur unground. A more marked influence of the hydrogen-ion concentration was noted, the range showing the greatest toxicity being between P_H 4.2 and 5.4. The increased toxicity at this point is attributed to one of 2 possibilities: first, the spores may be less resistant at this point, or second, the toxic form or conditions of sulphur may have been produced in greater amounts at this range. At any rate the hydrogen-ion concentration and the fineness of the particle contributed to the increased toxicity of the sulphur. The fineness of the particle did not seem to be the direct cause, as germ tubes grew normally after the initial retardation, even though they were directly in contact with the sulphur particles.

EXPERIMENT 3. COLLOIDAL SULPHUR

Sulphur readily assumes the colloidal state. The element sulphur has been known since the beginning of history, and records show that colloidal sulphur was prepared and studied as early as the seventeenth century. "Lac Sulfurus," a colloidal form of sulphur, was prepared in 1765 by Stahl (1766) and was used at that time for medicinal purposes. Fourcroy (1790), Berthollet (1798), Berzelius (1808), and Magnus (1827) were early contributors to the study of colloidal sulphur. Present-day methods for the preparation of colloidal sulphur are found in papers by Svedberg ('09), Himmelbauer ('09), Raffo ('08, '11), Odén ('13), v. Weimarn and Molyschew ('11), Kelber ('12), and others.

Colloidal sulphur exists in two forms, depending upon the degree of hydration. The form having a very high degree of hydration will be discussed in this paper as the hydrophilic colloidal sulphur and is identical with the product prepared by Raffo and Mancini ('11) and Odén ('13) and called "soluble

colloidal sulphur." The other form of colloidal sulphur is that first prepared by v. Weimarn and Molyschew ('11). This last has a very low degree of hydration and will be designated in this paper as hydrophobic colloidal sulphur. A more detailed description of these forms will be given in a subsequent section.

The hydrophilic colloidal sulphur was prepared according to the methods of Raffo and Mancini ('11) and Odén ('13) with certain modifications. Fifty gms. of pure crystalline sodium thiosulphate were dissolved in 30 cc. of distilled water; 70 gms. of concentrated sulphuric acid, sp. gr. 1.84, arsenic free, were weighed into a glass cylinder of 300 cc. capacity. The cylinder was placed in a vessel of cold water and the saturated solution of sodium thiosulphate added very slowly with occasional stirring. The mixture was then allowed to cool and 30 cc. of distilled water added. It was then placed on the water bath and warmed at 80° C. for 10 minutes, and filtered through glass wool to remove insoluble sulphur. The filtrate was cooled and allowed to stand for 12 hours. It was again warmed, filtered through glass wool, and the filtrate cooled. This warming, filtering, and cooling was repeated until no more insoluble sulphur came down. The final filtrate was a slightly turbid yellowish solution. This was centrifuged for 30 minutes at 1500 revolutions per minute. A portion of the colloidal sulphur was thrown out of solution. The supernatant liquid was a clear yellowish solution and was saved for further purification. The residue was washed in cold distilled water and again centrifuged for the same length of time and at the same speed. The supernatant liquid was again yellowish and was saved. The washing and centrifuging of the residual colloidal sulphur were repeated until the residue peptized in water gave a reaction of P_H 4.2. This colloidal suspension was faintly yellow and upon standing 1 week some of the particles settled out, the solution retaining its faint yellow color. Upon drying and weighing, the suspension gave a percentage of sulphur of 3.4.

The supernatant liquids collected from the above were treated with a concentrated solution of sodium chloride, whereby the yellowish colloidal sulphur was coagulated. The sodium chloride was added until no more coagulum seemed to form. The coagulum was easily centrifuged out and repeptized in 10 cc. of distilled water. The color of this solution was a deeper yellow and only very slightly turbid. This colloidal suspension gave a reaction

of P_H 4.2 and did not settle out on standing for 2 months. On drying and weighing, the solution was found to contain 1.6 per cent sulphur. This latter preparation was a typical hydrophilic colloidal sulphur and was more nearly a true "soluble" sulphur than the product obtained from the method of Raffo and Mancini ('11). The first preparation was a mixture of hydrophilic and hydrophobic colloidal sulphur. Odén ('13), in a detailed study of this type of colloidal sulphur mixtures, found them to contain particles of different sizes ranging from the molecular to particles easily discernible under the low power of the microscope. He was able to obtain suspensions with particles varying from the smallest to the largest by fractional coagulation with sodium chloride. Particles of larger size were more easily coagulated than the smaller ones. In colloidal sulphur suspensions of this kind the particles have a tendency to collect themselves into groups, forming larger particles which settle out rapidly. The smaller the particles the slower this takes place and in hydrophilic colloidal sulphur suspensions only a small amount of settling out can be noted after several months.

The chemical reactions involved in the formation of colloidal sulphur prepared by this method is given by Odén as follows:

$$Na_2S_2O_3 + H_2SO_4 = Na_2SO_4 + H_2S_2O_3$$
$$H_2S_2O_3 = SO_2 + H_2O + S$$
$$2\,H_2S_2O_3 = 2H_2S + 2SO_2$$
$$2\,H_2S + SO_2 = H_2O + S$$

$$3H_2S_2O_3 = 3H_2O + H_2SO_4 + S + S$$

Further chemical reactions will be given in a subsequent section of this paper.

The method for the preparation of hydrophilic colloidal sulphur was later varied in accordance with the method used by Freundlich and Scholz ('22). After the filtration through glass wool concentrated sodium chloride was added and the mixture centrifuged. The coagulum was then peptized with 100 cc. of distilled water and the insoluble sulphur centrifuged out. The peptized sulphur solution was treated 3 times with 25 cc. of saturated sodium chloride and finally peptized in 100 cc. of distilled water.

Another method for the preparation of hydrophilic colloidal sulphur was that first used by Selmi ('52) and was as follows. Sulphur dioxide was passed into distilled water until a saturated

solution was formed. Hydrogen sulphide was then passed into the sulphurous acid solution, care being taken not to have an excess of the hydrogen sulphide, as it precipitates the hydrophilic colloidal sulphur forming the hydrophobic colloid. The solution was then centrifuged to remove the larger particles and the supernatant liquid coagulated with sodium chloride. The coagulum was then peptized in water as before.

The hydrophobic colloidal sulphur can be prepared in a number of ways. It is the "milk of sulphur" formed when sulphur is precipitated out of solution. It was prepared in this work by the method used by v. Weimarn and Molyschew ('11) which was as follows: Sulphur was recrystallized in toluol and the toluol evaporated off at 60–70° C. Five-tenths gm. of this was heated with 125 cc. of fresh distilled absolute alcohol in a reflux condenser for 60 minutes. Seven cc. of this hot solution were poured into 293 cc. of distilled water at room temperature. The suspension prepared in this way was white and turbid. This was centrifuged and resuspended in water. The sulphur particles settled out of this suspension in a comparatively short time.

In determining the toxicity of these forms of colloidal sulphur the same method was used as in the preceding tests. With the hydrophilic colloidal sulphur, however, it was necessary to make a much weaker suspension. The stock colloidal suspensions contained about 1.5 per cent sulphur. Five cc. of this stock suspension were diluted to 25 cc. with distilled water, and then 1 cc. of this was added to each of the hydrogen-ion concentrations. This gave a further dilution of 1:5 and resulted in a very weak suspension of colloidal sulphur. After a preliminary test, however, the hydrophobic colloidal sulphurs were not diluted with water, and 1 cc. of the stock suspension was added directly to the culture solutions. The organisms used and the results are recorded in table I and figs. 1–4.

With the 6 organisms used in this experiment hydrophilic colloidal sulphur was found to be extremely toxic in the very dilute suspensions used. Only 2 of the organisms, namely, *Botrytis cinerea* and *Macrosporium sarcinaeforme*, showed a slight resistance to this suspension. In stronger suspensions germination was entirely inhibited with all the organisms used. On the other hand, hydrophobic colloidal sulphur was only slightly toxic and comparable to ground flowers of sulphur. The results indicate that sulphur is most toxic in a very finely divided state

such as is found in the hydrophilic colloidal sulphur. The influence of the hydrogen-ion concentration was very striking, especially with this latter form of sulphur. Upon examination of the culture tubes containing the hydrophilic colloidal sulphur it was found that settling out was rapidly increased as the P_H increased beyond P_H 5.4.

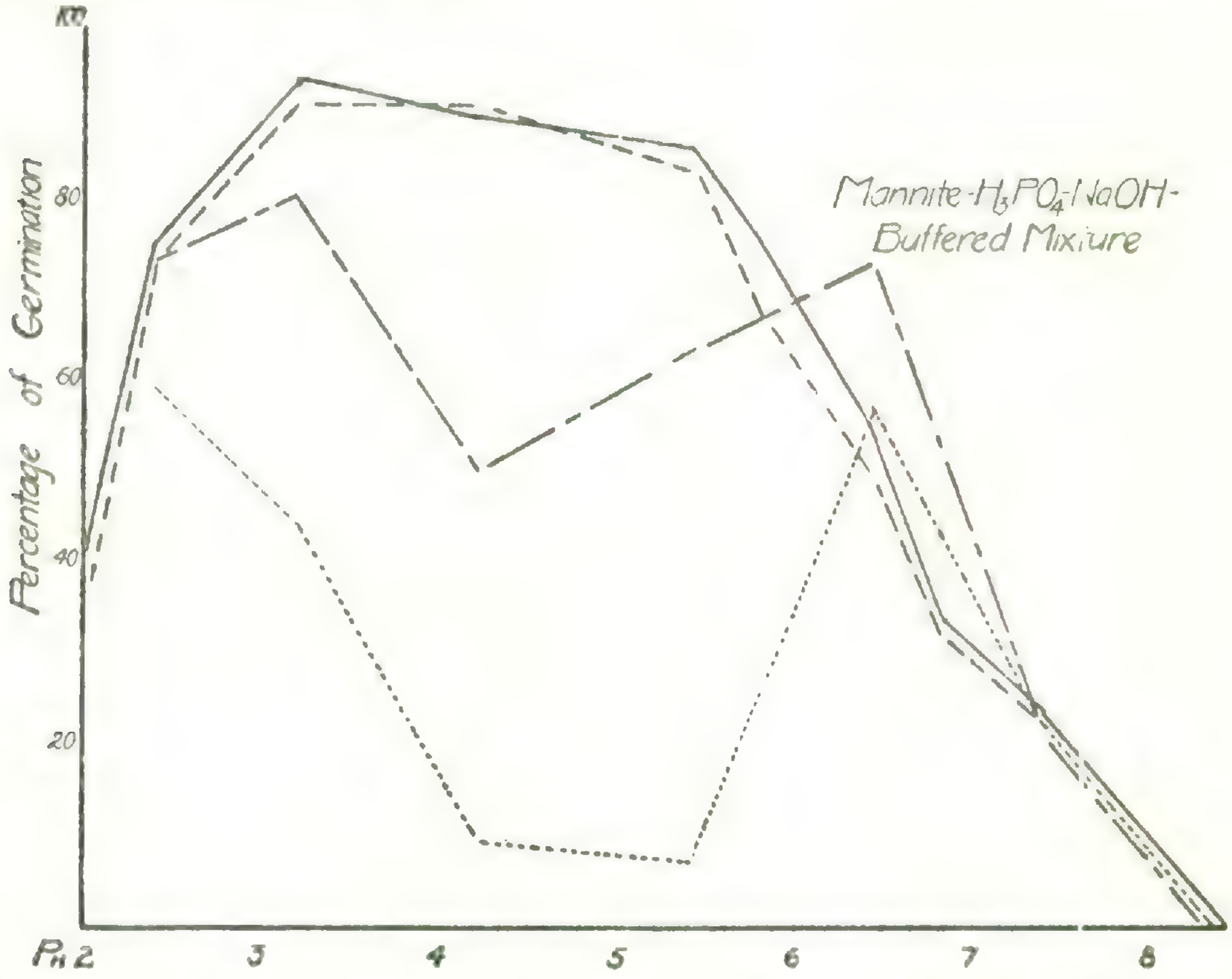

Fig. 1. Germination of spores of *Botrytis cinerea* in hanging-drop cultures: toxic action of flowers of sulphur ————————; of hydrophobic colloidal sulphur ————————; of hydrophilic colloidal sulphur ·····; check, without sulphur ————————.

EXPERIMENT 4. THE TOXICITY OF LIME SULPHUR

The compounds formed in lime sulphur mixtures have been fairly well determined by Haywood, Van Slyke, and others. The reactions that take place when sulphur and calcium oxide are boiled together are about as follows:

$$3Ca(OH)_2 + 12S = CaS_2O_3 + 2CaS_5 + 3H_2O$$
$$\text{or } 3Ca(OH)_2 + 8S = CaS_2O_3 + CaS_3 + 3H_2O$$

These reactions are influenced, of course, by the initial ratio of the ingredients. Varying amounts of CaS_3, CaS_4, CaS_5, CaS_2O_3 and $CaSO_3$ are formed depending upon this ratio. When lime sulphur is prepared according to the Van Slyke method, that is,

boiling together 80 lbs. of sulphur, 36 lbs. of lime, and 50 gallons of water, the first reaction is the more probable one. When prepared in this way the mixture has about the following composition: sulphur as sulphides (largely pentasulphides), 80.7 per cent, as thiosulphates, 19 per cent, as sulphites and sulphates, 0.03 per cent.

Lime sulphur mixtures are extremely alkaline and their initial efficiency as a fungicide may be due partly to this causticity, that is, to the free hydroxyl ions. An experiment was performed to determine how long this causticity remained when the spray

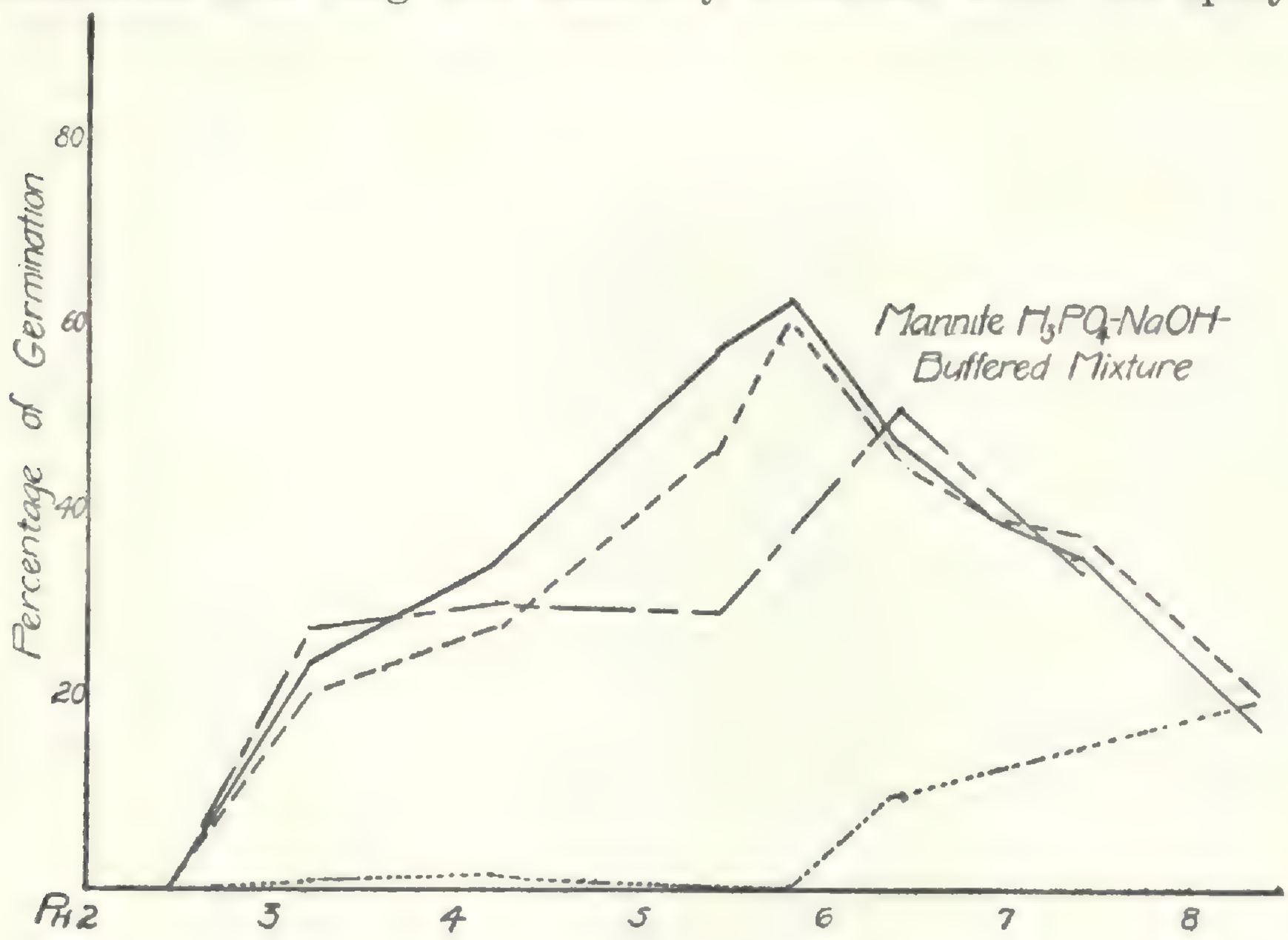

Fig. 2. Germination of spores of *Colletotrichum Gossypii* in hanging-drop cultures: toxic action of flowers of sulphur — — — —; of hydrophobic colloidal sulphur ————; of hydrophilic colloidal sulphur ·····; check, without sulphur ————.

was applied, and to ascertain, if possible, whether this factor was the principal one in giving lime sulphur its prolonged effectiveness as a fungicide. For this purpose lime sulphur was prepared according to the formula given by Van Slyke, and 1 part of the lime sulphur diluted with 6 parts of water. This is a little stronger than the concentration used as a dormant spray. Twelve large moist chambers were sprayed with this mixture and kept under the following conditions: Four were exposed to dry air; a second set of 4 was placed under slightly humid conditions, and a third set of 4 in a saturated condition. After 2 hours

the lime sulphur was washed from 1 of the exposed glass dishes and the reaction determined. It was found to have changed from an initial reaction of beyond the alkaline P_H range of indicators available (P_H 10.0) to P_H 6.4. Likewise, at the end of the same length of time the mixture was washed from one of the vessels in the second set and tested for its reaction. The reaction in this case remained beyond P_H 10.

At the end of 6 hours the reactions were again determined. The wash from the first set remained the same. In the second set the reaction had changed to P_H 7.4 and in the third set it was still beyond P_H 10. At the end of 24 hours a third set of readings

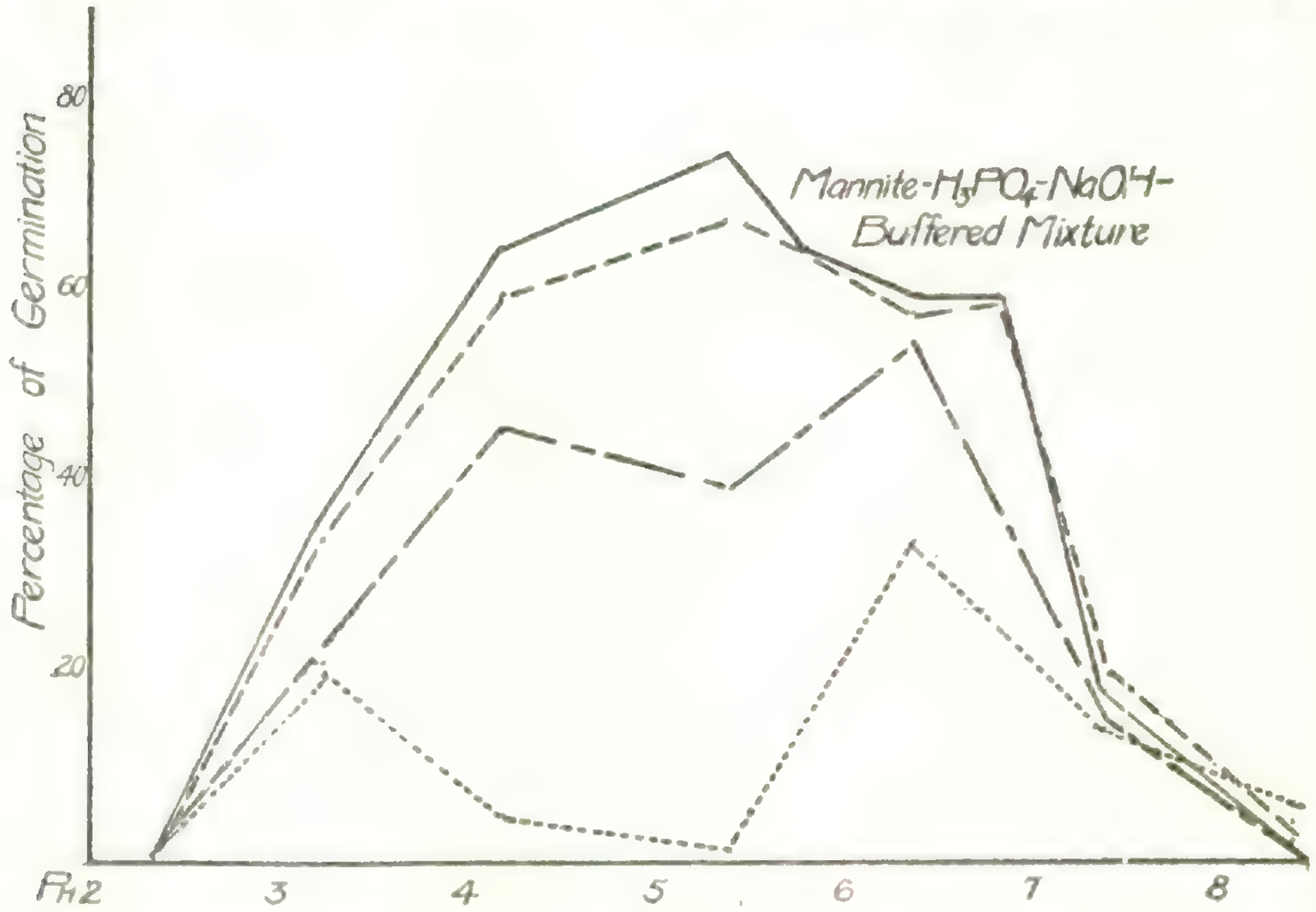

Fig. 3. Germination of spores of *Gloeosporium venetum* in hanging-drop cultures: toxic action of flowers of sulphur— — — — —; of hydrophobic colloidal sulphur — ——— ———; of hydrophilic colloidal sulphur .....; check, without sulphur ————.

was made. All gave the same reaction, P_H 6.4. The mixture placed under the third condition did not dry out, but changed in reaction to the same point as the others. It would appear from these results that the lasting action of lime sulphur is not due to its causticity.

At this point it was thought advisable to make some chemical determinations of the exposed or changed lime sulphur. Using the same method as that listed by the Association of Official Agricultural Chemists ('20) it was found that polysulphides were absent. The percentage of thiosulphates as determined by the

Shaffer and Hartman method ('21) was 1.4. Sulphides were found to be approximately 0.1 per cent. Precipitated sulphur as determined by the carbon bisulphide method gave a percentage of 2.8. We have present then in the changed lime sulphur, precipitated sulphur, calcium thiosulphate, calcium sulphite, and calcium sulphate.

The toxicity of these individual compounds was next determined. Fifty cc. of 1:6 lime sulphur solution were set aside in a large open vessel. After 36 hours the reaction had changed to P_H 6.4. The solution was then removed and the vessel washed with

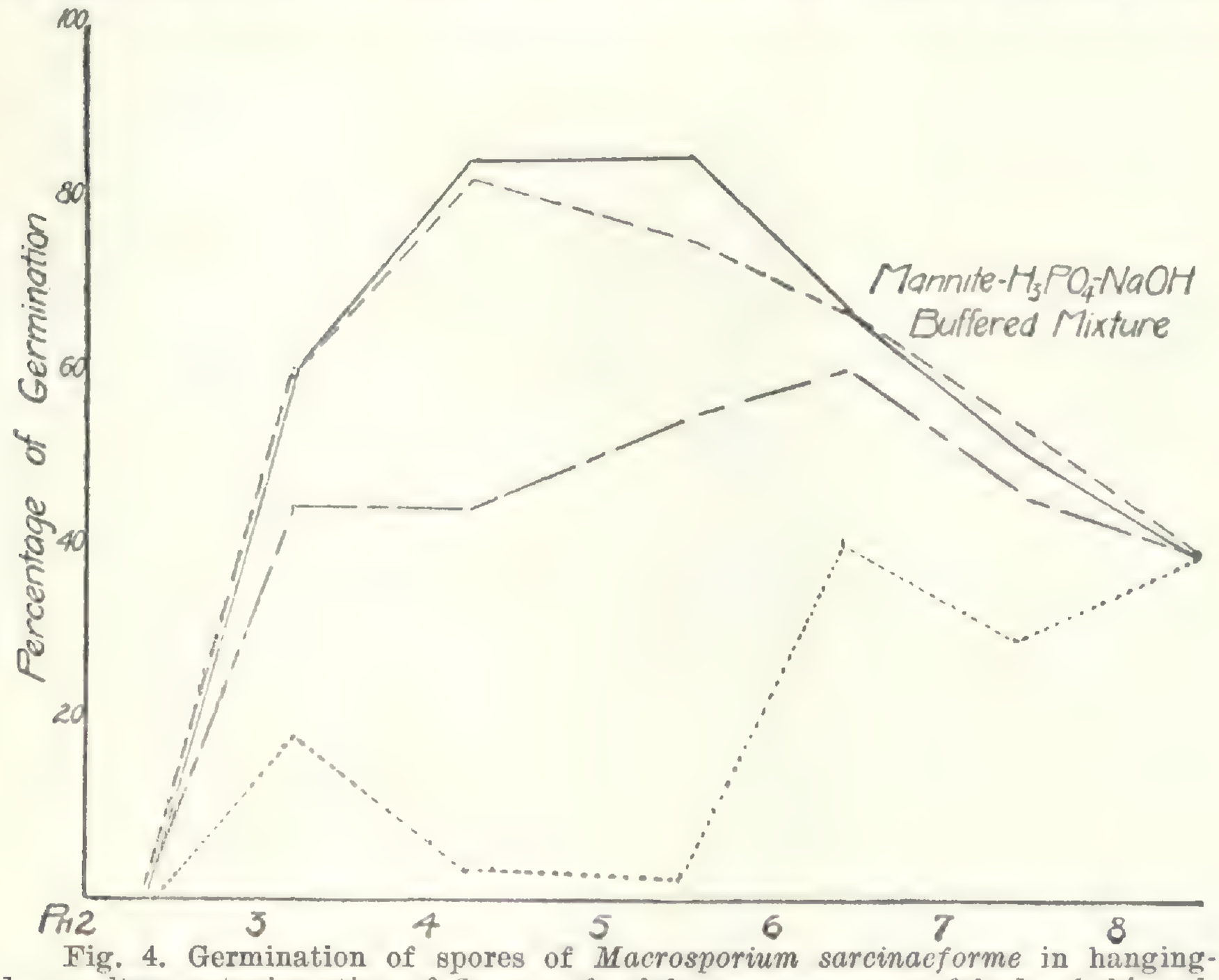

Fig. 4. Germination of spores of *Macrosporium sarcinaeforme* in hanging-drop cultures: toxic action of flowers of sulphur ——————; of hydrophobic colloidal sulphur – —— –——–; of hydrophilic colloidal sulphur .....; check, without sulphur ————————.

sufficient distilled water to make the total quantity up to the original 50 cc. This mixture was then centrifuged until the supernatant liquid was clear. A test was then made for calcium thiosulphate in the supernatant liquid. The percentage was 1.4. The part thrown out of the solution by the centrifuge was again washed in cold water and again centrifuged. The washing removed any soluble compound that might have been present. This washed substance was then suspended in 50 cc. of distilled water. The compounds contained in this suspension were the insoluble

compounds that were formed in the changed lime sulphur, such as the sulphites and sulphates and the precipitated sulphur. The toxicity of these compounds was determined in the same way as in the preceding experiments.

The calcium thiosulphate solution did not inhibit germination of any of the organisms used. Similar results were obtained by Armstrong ('21) in his studies on sulphur nutrition of the fungi. Accordingly, calcium thiosulphate cannot be a factor, even at this high concentration, in the fungicidal value of lime sulphur.

One cc. of the precipitated sulphur suspension was placed in each of the tubes containing the slightly buffered solution. This made a further dilution of 1:5, making this final suspension equal to that of the original changed lime sulphur, that is, 1:6. The toxicity was determined in the same way as in the preceding tests. The results are given in table 1.

The results were very similar to those obtained with colloidal sulphur. The hydrogen-ion concentration influenced the toxicity in the same general way. To make sure that this toxicity was not due to the sulphites and sulphates the sulphur was coagulated out as in the case of colloidal sulphur and the toxicity again determined. The results were the same. A further test was made, using a 0.1 per cent solution of calcium sulphite, but no toxicity resulted. An attempt was next made to try to further purify the sulphur suspension by fractional centrifugation, in which the centrifuge was run very slowly, thus throwing out the sulphur and not the insoluble calcium sulphites. By repeating the centrifuging 5 or 6 times a sulphur suspension was obtained which when dried was completely soluble in carbon bisulphide. The results with reference to toxicity were the same as those cited above.

It must be concluded from these results that the lasting fungicidal value of lime sulphur is due almost entirely to the precipitated sulphur, directly or indirectly, and not to the calcium thiosulphate and the insoluble sulphites. The precipitated sulphur formed in the changed lime sulphur is not in as finely divided state as the soluble colloidal sulphur prepared by the above methods, as was shown by the slow speed with which it could be thrown out of suspension. However, its toxicity was slightly greater than that of the hydrophobic colloidal sulphur in the same concentration.

TABLE I

PERCENTAGE OF GERMINATION*

Organism	Form of Sulphur	Hydrogen-ion concentration (P_H)									
		1.6	2.4	3.2	4.2	5.4	5.8	6.4	6.8	7.4	8.4
Botrytis cinerea	Without sulphur	4	76	94	90	86	76	56	34	24	0
	Flowers of sulphur	4	74	91	91	84	68	51	33	23	0
	Ground flowers of sulphur	4	66	78	49	68	—	52	—	16	0
	Hydrophilic colloidal sulphur	6	60	45	10	8	—	58	—	23	0
	Hydrophobic colloidal sulphur	4	74	81	51	64	—	74	—	21	—
	Precipitated lime sulphur	—	60	52	20	16	—	17	22	18	—
Colletotrichum Gossypii	Without sulphur	0	0	24	35	57	64	48	40	36	18
	Flowers of sulphur	0	0	21	28	47	61	46	40	38	21
	Ground flowers of sulphur	0	0	23	25	28	—	35	—	30	—
	Hydrophilic colloidal sulphur	0	0	1	1	0	0	10	—	15	20
	Hydrophobic colloidal sulphur	0	0	28	31	30	—	52	—	34	—
	Precipitated lime sulphur	0	0	12	13	11	—	26	—	28	—
Sclerotinia cinerea	Without sulphur	0	48	72	94	82	80	76	29	3	0
	Flowers of sulphur	0	0	0	0	0	0	0	0	0	0
	Hydrophilic colloidal sulphur	0	0	0	0	0	0	0	0	0	0
Gloeosporium venetum	Without sulphur	0	4	36	65	75	65	60	60	18	2
	Flowers of sulphur	0	3	34	60	68	65	58	59	21	4
	Ground flowers of sulphur	0	3	21	46	40	—	55	—	15	3
	Hydrophilic colloidal sulphur	0	4	20	5	1	—	34	—	14	6
Macrosporium sarcinaeforme	Without sulphur	0	4	60	85	86	—	68	—	52	40
	Flowers of sulphur	0	4	61	83	76	—	68	—	55	41
	Ground flowers of sulphur	0	4	45	45	56	—	61	—	48	40
	Hydrophilic colloidal sulphur	0	0	19	3	2	—	41	—	30	38
Phomopsis Sojae	Without sulphur	0	0	1	42	31	83	—	63	37	26
	Flowers of sulphur	0	0	0	0	0	0	0	0	0	0

* Average of 6–12 replications conducted at 3 different times.

EXPERIMENT 5. THE TOXICITY OF THE VOLATILE PRODUCTS OF SULPHUR

The results of the foregoing experiments indicate that sulphur is most toxic when it is in a finely divided state, this toxicity increasing in proportion to the fineness of the particle, hydrophilic colloidal sulphur exhibiting the highest degree of toxicity. The prevailing supposition that sulphur is only toxic when in a volatile state might be justified by the assumption that finely di-

vided sulphur yields a volatile product more readily. On the other hand, the peculiar relation of this toxicity to a definite range of hydrogen-ion concentration points rather towards the probability that sulphur is toxic because of a compound produced that may be volatile, the production of this compound being affected directly by the reaction. It does not seem probable that the colloidal sulphur particle as such could be rendered non-toxic by so slight a change in reaction as has been shown to govern its fungicidal property.

To determine these points a series of experiments was arranged, using flowers of sulphur, hydrophilic and hydrophobic [1] colloidal sulphur. The organisms used were *Botrytis cinerea, Colletotrichum Gossypii,* and *Sclerotinia cinerea.* The method of procedure was the same as in the preceding experiments, with the following modifications: The spores were placed in drops of the slightly buffered solution without sulphur. The sulphur suspensions were placed only at the bottom of the cells. In this way the spores were not in direct contact with the sulphur, the distance between culture drop and cell liquid being the height of the cell, which was 8 mm. The cultures were incubated at 22° C. The results are given in table II.

TABLE II

PERCENTAGE OF GERMINATION

Organism	Form of Sulphur	Hydrogen-ion concentration (P_H)									
		1.6	2.4	3.2	4.2	5.4	5.8	6.4	6.8	7.4	8.4
Botrytis cinerea	Without sulphur	4	76	94	90	86	76	56	31	10	0
	Flowers of sulphur	4	74	91	91	84	78	51	33	—	—
	Hydrophilic colloidal sulphur	3	60	58	12	8	54	61	50	—	—
	Hydrophobic colloidal sulphur	4	71	95	84	90	74	52	32	—	—
Colletotrichum Gossypii	Without sulphur	0	0	24	38	53	55	58	46	—	—
	Flowers of sulphur	0	0	22	37	51	50	59	45	—	—
	Hydrophilic colloidal sulphur	0	0	10	0	0	21	43	47	—	—
	Hydrophobic colloidal sulphur	0	0	26	28	44	53	61	42	—	—
Sclerotinia cinerea	Without sulphur	0	51	84	95	82	70	57	9	3	0
	Flowers of sulphur	0	50	66	70	74	65	58	11	0	0
	Hydrophilic colloidal sulphur	0	0	0	0	0	3	24	14	2	0
	Hydrophobic colloidal sulphur	0	36	19	8	10	65	59	11	—	—

[1] Precipitated sulphur.

The results in this table are very similar to those recorded in table 1 except that the flowers of sulphur exhibited no toxic action even to *Sclerotinia cinerea* and the hydrophobic colloidal sulphur was only slightly toxic with *Botrytis cinerea* and *Colletotrichum Gossypii*. The hydrophilic colloidal sulphur exhibited the usual degree of toxicity, regardless of the fact that it was a considerable distance from the spore. Toxicity was greatest in all cases at P_H 4.0–5.5, as in the previous tests.

Having determined that the toxic substance is volatile, it was thought necessary at this point to eliminate, if possible, hydrogen sulphide, sulphur dioxide, and sulphur trioxide, as factors. For these tests *Sclerotinia cinerea* was selected because it has proved to be quite sensitive to the toxic action of sulphur. Spores were placed over a saturated solution of hydrogen sulphide in a Van Tieghem cell and the cultures were incubated at 22° C. for 24 hours. Germination was not inhibited. The experiment was repeated with *Colletotrichum Gossypii* and *Botrytis cinerea* with similar results.

No toxicity could be noted with sulphur dioxide in a concentration sufficient to kill when converted into hydrophilic colloidal sulphur by the addition of hydrogen sulphide.

Sulphuric acid inhibited growth only because of its acidity, accordingly, in proportion to acidity. Positive tests for sulphur dioxide and trioxide could not be obtained in aerated sulphur suspensions that were toxic to *Sclerotinia cinerea*. These compounds, therefore, do not contribute to the toxic properties of sulphur.

EXPERIMENT 6. THE INFLUENCE OF O_2 ON THE TOXICITY OF SULPHUR

In all of the foregoing tests the only oxygen available was that present in the air enclosed in the closed-ring cells. An experiment was conducted to determine the effect of oxygen on increasing the toxicity of flowers and precipitated sulphur. Finely ground flowers of sulphur and hydrophobic colloidal sulphur were placed in the slightly buffered mixtures in the same concentration as in Experiments 1 and 2. The Van Tieghem cells were placed in Petri dishes, the bottoms of which were lined with filter-paper in which holes somewhat larger than the glass rings were cut, so that the cells might rest on the bottoms of the Petri dishes. A large drop of the sulphur suspension was placed at

the bottom of the ring. The filter-paper was saturated with water. Spores of *Sclerotinia cinerea* were placed in a drop of the culture medium without sulphur, on a cover slip which was inverted over the cell. The cells were not sealed at the top or bottom.

In the same Petri dish sealed cells were prepared. This was done for each hydrogen-ion concentration. The Petri dishes containing the cultures were arranged in a moist chamber through which air was passed. This experiment was conducted at room temperature and the percentage of germination noted after 18 hours. The results are given in table III.

TABLE III

PERCENTAGE OF GERMINATION*
SCLEROTINIA CINEREA

P_H	Ground flowers of sulphur		Hydrophobic colloidal sulphur	
	$-O_2$	$+O_2$	$-O_2$	$+O_2$
2.4	40	38	34	24
3.2	64	49	17	10
4.2	68	31	8	0
5.4	65	24	11	0
5.8	62	46	54	32
6.4	58	49	48	44

*Average of triplicate cultures.

Another experiment was conducted, in which a weak suspension of hydrophobic colloidal sulphur which did not inhibit the germination of spores of *Colletotrichum Gossypii* at any hydrogen-ion concentration was aerated for 24 hours. Air from which the oxygen was removed with pyrogallol [1] was passed through a duplicate series. The toxicity was determined with spores of *C. Gossypii* in closed-ring cells in the same manner as in Experiment I. Likewise, a similar series was arranged, using an aerated suspension of flowers of sulphur. The cultures were incubated at 22° C. and the percentage of spore germination determined after 18 hours. The results are recorded in table IV.

The results of these tests prove conclusively that the toxic property of sulphur is due to an oxidation product and that finely divided sulphur is more readily oxidized at ordinary temperatures than the ordinary sublimed sulphur.

[1] One part pyrogallol, 5 parts NaOH, and 30 parts H_2O.

TABLE IV

PERCENTAGE OF GERMINATION
COLLETOTRICHUM GOSSYPII

P_H	Hydrophobic colloidal sulphur		Flowers of sulphur	
	$-O_2$	$+O_2$	$-O_2$	$+O_2$
2.4	0	0	0	0
3.2	26	18	22	18
4.2	42	2	51	16
5.4	56	13	60	10
5.8	60	37	68	43
6.4	66	62	54	56

EXPERIMENT 7. THE INFLUENCE OF H_2O ON THE TOXICITY OF SULPHUR

The influence of water on this volatile compound was next studied. Dry colloidal sulphur was prepared by centrifuging hydrophobic colloidal sulphur and the residue dried at room temperature. This was placed in the bottom of Van Tieghem cells. Spores of *Sclerotinia cinerea* were placed in sterile distilled water on sterile cover slips and inverted over the cell. The cell was not made air-tight, thereby not eliminating any other factor except water. Checks were arranged in which a suspension was used instead of the dry sulphur, other conditions being the same. All the cultures were placed in a moist chamber at room temperature. There resulted from this experiment no inhibition when dry sulphur was used, while the suspension gave the same amount of inhibition as reported in table III. Oxygen and water are necessary factors in the formation of the toxic volatile compound of sulphur.

Chemistry of Hydrophilic Colloidal Sulphur

The results of all the foregoing experiments point towards hydrophilic colloidal sulphur as containing the toxic substance produced by the oxidation of the ordinary forms of sublimed and precipitated sulphur. It is as toxic in closed-ring cells where little oxygen is available as in open aerated cells. The other forms of sulphur tried are toxic only when oxygen is present. Hydrophilic colloidal sulphur is toxic at 21–22° C. to *Botrytis cinerea, Macrosporium sarcinaeforme, Gloeosporium venetum,* and *Colletotrichum Gossypii,* all of which are very re-

sistant and grow normally in a suspension of flowers of sulphur at temperatures below 25° C. Because of these facts it is logical to assume that the toxic property of sulphur is due to a compound formed by the oxidation of sulphur. Having eliminated the more common oxides and acids of sulphur it was thought that this toxic compound might be one or a mixture of the more complex polythionic acids. At any rate hydrophilic colloidal sulphur contains such an acid. The chemistry of hydrophilic colloidal sulphur has been studied by a number of investigators. Bary ('20) studied Raffo's soluble sulphur (here termed hydrophilic colloidal sulphur), and came to the conclusion that the substance contained not only sulphur but polythionates. He thought the solution was made stable by the presence of small amounts of electrolytes. Freundlich and Scholz ('22) made a very extensive study of the so-called soluble sulphur and concluded that it was largely pentathionic acid. They base their conclusion on the following reactions which would take place if pentathionic acid were present.

$$2NaOH + H_2S_5O_6 = Na_2S_3O_6 + S_2 + 2H_2O$$

$$2\,Na_2S_3O_6 + 6NaOH = Na_2S_2O_3 + 4\,Na_2SO_3 + 3\,H_2O + 4S$$

or $$2Na_2S_5O_6 + 6NaOH = 5Na_2S_2O_3 + 3\,H_2O.$$

By the aid of this reaction they were able to determine qualitatively and quantitatively the pentathionic acid. The qualitative test was made by the addition of an alkali which precipitated out the sulphur in the form of a white turbid solution. They state that this test applies only to pentathionic acid, and to no other sulphur compound containing oxygen, such as any of the well-known acids or oxides. The quantitative test is made by treating the colloidal solution with normal NH_4OH, forming ammonium thiosulphate and titrating this with 0.01N iodine solution. With hydrophobic colloidal sulphur these tests were negative. They designate colloidal sulphur in this form as S λ and the form associated with pentathionic acid as S μ. When S μ is precipitated out of hydrophilic colloidal sulphur it probably becomes S λ. Such a change also takes place when pentathionic acid is treated with H_2S.

According to these workers, sodium thiosulphate and sulphuric acid react as follows:

$$Na_2S_2O_3 + H_2SO_4 = H_2S_2O_3 + Na_2SO_4$$
$$H_2S_2O_3 = SO_2 + 3S + H_2O$$

By the action of remaining sulphuric acid,

$$H_2SO_4 + 5H_2S_2O_3 = 2H_2S_5O_6 + 3\,H_2O$$

The pentathionic acid then joins with sulphur (S μ) and water to form the hydrophilic colloid of the following structure:

$$\begin{array}{c} S_{\mu} \\ \cdot \\ S_5O_6\ H_2\ S_5O_6 \\ \cdot \\ H_2O \end{array}$$

The possibility of such a structure is based on the fact that a compound containing so many oxygen ions must necessarily have a great affinity for water. Moreover, a molecule containing so many sulphur atoms would, because of its residual valence, account for its combining with other atoms of sulphur. This being true, pentathionic acid would have the property of combining between molecules of sulphur and water. In other words, it is an adsorptive medium for both these substances. A similar phenomenon is described and illustrated by Langmuir ('17) in his studies of secondary valences in mixtures of fats and water.

Having no such adsorption medium present in hydrophobic colloidal sulphur, the S λ absorbs water and forms the grouping S λ· H_2O, which is a typical suspension colloid, poorly hydrated and gradually settling out.

The chemical nature of pentathionic acid has been very thoroughly studied. It was discovered by Wackenroder ('46) in 1845. He prepared the acid by passing H_2S into a saturated solution of SO_2, always keeping the excess of the latter. By calculations he arrived at the formula of $H_2S_5O_6$. For quantitative determinations he precipitated the acid with an alkali, in much the same way as reported by Freundlich and Scholz ('22) for hydrophilic colloidal sulphur. He also found that salts precipitated it.

After the discovery of this acid considerable controversy arose as to its existence in a pure state. Spring ('82) states that it is his opinion that the so-called pentathionic acid consists of a solution of sulphur in tetrathionic acid and that salts obtained from this solution are simply tetrathionates containing admixed sulphur. That this conclusion was partially correct was proved by Shaw ('83). He could produce pure pentathionic acid, but at times such an admixture as obtained by Spring would be obtained. A close relationship undoubtedly exists between pentathionic acid

and sulphur. Shaw prepared his pentathionic acid by passing simultaneously hydrogen sulphide and sulphur dioxide into 3 liters of distilled water for 32 hours, the sulphur dioxide being kept slightly in excess. This controversy was definitely settled by Debus ('88). His work is summed up by Mellor ('17) in the chapter on the compounds of sulphur and oxygen.

The properties of pentathionic acid have been more recently studied by Raschig ('20) and Riesenfeld and Feld ('21). The latter state that the action of H_2S and SO_2 forms the hypothetical acid $H_2S_3O_4$ as an intermediary product and that by its oxidation and reduction pentathionic acid is formed; they give the following reactions:

$$2SO_2 + H_2S = H_2S_3O_4$$
$$\left.\begin{aligned} H_2S_3O_4 + SO_2 &= H_2S_4O_6 \\ H_2S_3O_4 + 6SO_2 &= 2H_2O + H_2S_3O_6 \end{aligned}\right\} \text{Oxidation by } SO_2$$
$$H_2S_3O_4 + 3H_2S = 6S + 4H_2O\text{—Reduction by } H_2S$$
$$5H_2S_3O_4 = 3H_2S_5O_6 + H_2O\text{—Polymerization}$$

They studied the action of acid and alkali and found that the acid was unstable in both conditions.

It is therefore evident that the hydrophilic colloidal sulphur prepared according to the methods of Selmi ('52), Raffo ('08), Odén ('13), and others, is pentathionic acid. That this is an oxidation product of sulphur seems a logical conclusion. The influence of the hydrogen-ion concentration also points toward pentathionic acid as being the toxic factor in all of the preceding experiments. Flowers of sulphur, hydrophobic colloidal sulphur, and especially hydrophilic colloidal sulphur exhibited toxicity only at P_H 4.2–5.4, because of the fact that pentathionic acid is destroyed when in a solution of higher or lower hydrogen-ion concentration.

To obtain further proof of the toxicity of pentathionic acid the hydrophilic colloidal sulphur was freed of this acid. The colloidal sulphur was prepared by the following method, which is only a slight modification of the one used in previous experiments: Thirty cc. of a saturated solution of sodium thiosulphate were slowly added to 10 cc. of concentrated sulphuric acid. The mixture was warmed and filtered through glass wool. The filtrate was then coagulated with sodium chloride and centrifuged. The coagulum was peptized in 100 cc. of distilled water and again centrifuged to remove insoluble sulphur. Coagulation,

centrifuging, and peptizing were repeated 3 times, and the final coagulum peptized in 100 cc. of distilled water. The reaction of this peptized solution was P_H 4.2. Seventy-five cc. of this solution, for convenience designated No. 1, were treated with 25 cc. of normal ammonium hydroxide and let stand 24 hours, a white precipitate being formed. This was neutralized and centrifuged. The residue was suspended in 75 cc. of distilled water and designated solution 2. The filtrate, No. 3, was again treated with 25 cc. of normal ammonium hydroxide and left for 24 hours. A slight precipitate was formed. This was neutralized, the precipitated sulphur centrifuged out and suspended in 10 cc. of water, and this last designated solution 4; and the filtrate, No. 5. Seventy-five cc. of the filtrate, No. 5, were again treated with 25 cc. of normal ammonia and left for 24 hours. No precipitate formed. This was neutralized and called solution 6.

Fifty cc. of solution 2 were treated with 25 cc. of normal ammonium hydroxide and kept for 24 hours. It was then neutralized and centrifuged. The residue was suspended in 50 cc. of distilled water and designated solution 7. Twenty-five cc. of this solution were treated with 10 cc. of ammonia, allowing the usual interval, then again neutralized, centrifuged, and suspended in 25 cc. of water, constituting solution 8. A portion of each of these solutions was tested for pentathionic acid, with the result that Nos. 3, 5, 6, and 8 gave no positive test; Nos. 1, 2, and 7 gave positive tests, but 2 and 7 only a slight indication.

These solutions were then tested in respect to toxicity in closed-ring cells, using the spores of *Botrytis cinerea* and *Colletotrichum Gossypii*. The cultures were placed at 22° C. for 24 hours, and the results, which are averages of duplicate cultures, are given in table v.

TABLE V

PERCENTAGE OF GERMINATION

Organism	No. of solution								
	1	2	3	4	5	6	7	8	Ck.
Botrytis cinerea	0	10	50	41	55	55	26	54	53
Colletotrichum Gossypii	0	7	61	54	65	64	18	63	61

The amount of killing was directly proportional to the amount of pentathionic acid present. No. 8 contained as much sulphur as No. 1 but was not toxic.

Another experiment was conducted to ascertain if aerated flowers of sulphur produces pentathionic acid. Two lots of 50 gms. each of flowers of sulphur were placed in wash bottles. The 2 bottles were placed in series each connected with wash bottles containing distilled water to collect any volatile water-soluble compound that might come over. Air was passed through one series and air deprived of oxygen through the other. Aeration was continued for 72 hours. At the end of this time H_2S was passed into the distilled water wash bottles and permitted to stand for 12 hours. A slight precipitate was noted in the distilled water through which air containing oxygen had passed. The series without oxygen gave no precipitate. This afforded definite proof that pentathionic acid is an oxidation product of flowers of sulphur at ordinary temperatures. A concentrated solution of sodium chloride was added to the aerated sulphur suspensions, and centrifuged; the residue was resuspended in water and again centrifuged. Hydrogen sulphide was then passed into the supernatant liquid. A precipitate developed only in the one in which oxygen was present.

A similar series was arranged using precipitated sulphur containing no pentathionic acid. The distilled water containing the volatile soluble compound and the aerated suspension were tested for pentathionic acid. The former gave a slight precipitate with H_2S after standing. The suspension gave a much heavier precipitate indicating that the pentathionic acid was adsorbed by the sulphur particle and was not easily driven off by slow aeration. Without oxygen there was no pentathionic acid produced.

The precipitated sulphur was much more easily oxidized than the sublimed flowers of sulphur.

Practical Applications

Time has not permitted a more extensive study of this phase of the problem. It was necessary in the first place to determine the compound of sulphur that is toxic to fungi and to develop a material that would act as a fungicide over a sufficient period when sprayed on the plant. The fact that flowers of sulphur must be acted upon by some definite external physical factor has limited its use to only a small section of the country. It has been the aim in this work to develop, if possible, a sulphur compound that would exhibit fungicidal properties regardless of climatic factors and would for that reason have a wide usage over a large

part of the country. To accomplish this the material must yield readily the toxic compound, pentathionic acid. The reaction must be kept slightly acid (P_H 4.0–5.5), as this toxic compound is destroyed above or below this point. It must be readily oxidizable at ordinary temperatures. It should have great adhesiveness; it must not burn the leaves.

Colloidal sulphur has all these properties when tested in the laboratory and greenhouse. It is almost impossible to wash it from the leaves of plants after it has dried. It is difficult to remove it with a strong stream of water. Certainly rain would have little effect upon it.

That colloidal sulphur is readily oxidized has been demonstrated in the foregoing experiments. Kuhl ('21) states that colloidal sulphur bears the same relation to atmospheric oxygen as phosphoric iron, the latter being self-inflammable.

Methods for the preparation of colloidal sulphur mixtures for fungicidal use are being experimented upon. The hydrophilic colloidal sulphur prepared by the method given above is suitable as a spray. It did not burn the leaves of bean, potato, tobacco, rose, and geranium when sprayed on them. By the use of commercial materials this mixture is not too costly for practical purposes. Other methods for its preparation are being tried.

The method for the preparation of hydrophobic colloidal sulphur for trials in the greenhouse was as follows: One gallon of commercial or home-made lime sulphur was diluted with 5 gallons of water. Commercial phosphoric acid was added until the reaction was slightly acid. A milky precipitate of colloidal sulphur was formed. The mixture was allowed to stand a day or two to remove excess H_2S, and then applied. The advantage of phosphoric acid over other acids is that the calcium acid phosphate formed maintains the proper reaction. This mixture diluted 1:5 with water prevented the germination of *Botrytis cinerea* and *Colletotrichum Gossypii* in aerated cultures. When sprayed on the plant this type of colloidal sulphur does not stick as well as hydrophilic colloidal sulphur but no doubt can be made just as effective a spray by the addition of soluble glue or other suitable spreaders. Any precipitated sulphur to which has been added calcium acid phosphate or another suitable compound for maintaining the slightly acid reaction should be an effective fungicide.

With respect to increasing the value of flowers of sulphur as a spray the writer is not yet prepared to make a definite recom-

mendation. However, the fact that this substance is slowly oxidized at ordinary temperatures leads to the possibility of its being used effectively when treated with compounds that will increase its oxidation. It will also be necessary to add to such a spray an adsorptive material to retain the pentathionic acid as it is produced. Many of the common spreaders now in use may do this. These possibilities are being investigated and will be reported later.

Since the completion of the experimental part of this work there has come to my attention a number of colloidal sulphur preparations that have proved effective as a general spray. Ramsay and Cooke ('22) have prepared a colloidal sulphur that has been used effectively in Australia. They prepare their compound as follows: Ten gallons of home-made lime sulphur (26° Baumé) are diluted with 25 gallons of water in a barrel of 50 gallons capacity. In a suitable vessel 6 pints of strong commercial sulphuric acid are diluted with 9 parts of cold water and allowed to cool. The cold diluted sulphuric acid is then carefully added to the dilute lime sulphur in the barrel, a pint at a time, stirring well until the typical yellow color of the original lime sulphur disappears and until further addition of more acid produces no further precipitation of sulphur. The precipitated sulphur is allowed to settle for a day or two. Three pounds of cheap glue are dissolved in sufficient hot water to render the glue soluble and while still hot is stirred thoroughly into the sulphur. The glue aids in the keeping qualities of the colloidal sulphur. The mixture so prepared is diluted to 250 gallons (with water). This gives a spray containing approximately 5 pounds of precipitated sulphur per 100 gallons.

Thiele ('21) recommends the use of colloidal sulphur in the form of a liquid spray (not dust) for the control of mildews in Germany. He states that it is far more effective than the most finely ground sulphur powder. The colloidal mixtures adhere firmly to the plant and are not blown away by the wind or washed off by rains, as is the powder. Precipitated sulphur as a control for mildew and related fungi has been recommended by Lederle ('22). He prepared this precipitated sulphur as follows: Solution I: 250 gms. of sodium hyposulphite are dissolved in ¾ liter of hot water. Solution II: 250 gms. of sodium bisulphate are dissolved in ¾ liter of hot water. Solution III: 10 gms. of glue are dissolved in ¼ liter of hot water. Solution III is then stirred

while hot into solution I. After diluting solutions I and II each with 4 liters of water they are mixed and let stand for 3–18 hours when the mixture is ready for use. It is somewhat unstable and should be used within a few days, preferably the next morning.

Kuhl ('21) experimented with De Haen's colloidal soluble sulphur [1] and found it to be very effective in controlling mildews and related diseases. He stated that the mixture was very adhesive and that it did not burn the leaves. He believed that the increased effectiveness of this type of sulphur over other sulphur sprays was due to its increased chemical activity.

Barker and Wallace ('22) describe a new method for sulphur fumigation for the greenhouse. In previous studies they found that the fungicidal value of sulphur depended upon its being applied as extremely finely divided particles. Their method is as follows: Air is passed through molten sulphur in a Campbell's "sulphur vaporiser," the temperature of the sulphur being kept just above the melting point and well below the ignition point. The melting point of sulphur is about 115° C. and its ignition point in the air is about 260° C. The most satisfactory temperature is around 170° C. Under these conditions an abundant cloud of sulphur in the particulate condition is produced. An improvement in the yield of particulate sulphur is effected if the current of air is passed into the molten sulphur through a perforated nozzle. By means of an attached delivery tube the particulate sulphur can be discharged in any given direction and on to any definite object. It can be used for general fumigation or for direct spraying.

Another method for fumigation has been described by Vogt ('21), and is as follows: Three-hundred gms. of pure roll sulphur (stick sulphur) contained in a small iron pan is liquefied and brought to the boiling point (448° C.). There is heated at the same time in a circular copper boiler 400 gms. of water. The strongly superheated steam of the latter is forced under high pressure through the boiling sulphur which vaporizes it into small mist-like drops. These drops preserve their liquid form for several hours. They possess a high degree of adhesion not otherwise common to sulphur and do not burn the leaves. A few gms. of sulphur are enough to fill an average greenhouse with clouds of vapor which in a very short time covers all free surfaces.

[1] Manufactured by De Haen at Seelze.

A strong stream of water from the hose did not remove the sulphur from panes of glass. The method is being perfected for open-air use.

Conclusions

1. Flowers of sulphur is not sufficiently toxic to inhibit the germination of spores of *Botrytis cinerea, Colletotrichum Gossypii, Macrosporium sarcinaeforme,* and *Gloeosporium venetum* in closed-ring cells at ordinary temperatures. Spores of *Sclerotinia cinerea* and *Phomopsis Sojae* were inhibited from germination.

2. Finely ground flowers of sulphur was more toxic than the unground flowers under the same conditions but only at a hydrogen-ion concentration of P_H 4.0–5.5.

3. Methods for the preparation of hydrophilic and hydrophobic colloidal sulphur have been devised.

4. Hydrophilic colloidal sulphur was extremely toxic to all the organisms used.

5. Hydrophobic colloidal sulphur was slightly more toxic than the finely ground flowers of sulphur.

6. The chemical and fungicidal properties of lime sulphur were studied. Before application lime sulphur contains 80.7 per cent sulphur as calcium sulphides, 19 per cent as calcium thiosulphate, and .03 per cent as sulphites and sulphates. After exposure to the air for a few hours as a spray the sulphides disappear and increasing amounts of sulphur are formed. The lasting effectiveness of the mixture is due to the precipitated sulphur which is about as toxic as hydrophobic colloidal sulphur.

7. The toxic property of sulphur is not due to SO_2, SO_3 or H_2S, or any of the common acids or oxides of sulphur, or to the sulphur particle. Germ tubes grew normally in a heavy suspension of precipitated sulphur in closed-ring cells.

8. The toxic property of sulphur is only exhibited when oxygen and water are present.

9. By chemical analysis the toxic property of sulphur has been found to be pentathionic acid which is an oxidation compound formed from sulphur and water.

10. Pentathionic acid is volatile and is an active adsorption compound. It is destroyed in acid and alkaline solutions.

11. Finely divided sulphur is more readily oxidized to pentathionic acid at ordinary temperatures than is the flowers of sulphur.

12. Finely divided sulphur has been used as a spray in England, Australia, and Germany, with excellent results.

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GENERAL INDEX TO VOLUME IX

New scientific names of plants and the final members of new combinations are printed in **bold face** type; synonyms and page numbers having reference to figures and plates, in *italic;* and previously published scientific names and all other matter, in ordinary type.

A

abietina (Clavaria), 20
Acidity and alkalinity, principles involved in determination of, 353
acris (Clavaria), 23
Actinomyces Sojae, germination of spores of, in sulphur compounds, 408
Acurtis gigantea, 68
Agropyron, bacterial diseases of, 333
albida (Clavaria), 18
albipes (Calocera), 65
albipes (*Clavaria*), 65
amethystina (*Clavaria*), 41
amethystina (*Coralloides*), 41
amethystina (*Ramaria*), 41
amethystinoides (Clavaria), 42
Andropogon, bacterial diseases of, 333, 342
Aplanobacter Agropyri, 338; Rathayi, 336
Arabis longirostris, 310
arborea (Clavaria), 30
Ardenia (*Clavaria*), 59
argillacea (Clavaria), 53
Arrhenatherum, bacterial disease of, 339
asperula (Clavaria), 33
asperulans (Clavaria), 34
asperulospora (Clavaria), 60
asterella (Clavaria), 37
aurantio-cinnabarino (Clavaria), 43
aurea (Clavaria), 13
Avena, bacterial diseases of, 333, 342

B

Bacillus cerealium, 334; Sorghi, 335
Bacterial disease of foxtail, 333, general description of, 340; of Gramineae, 333
Bacterium Andropogoni, 335; atrofaciens, 339; coronofaciens, 338; moniliformans, 336; translucens, 338, var. undulosum, 339
Berkeleyi (Clavaria), 61
bicolor (Clavaria), 61
bicolor (*Clavaria*), 67
bicolor (*Lachnocladium*), 65
biformis (Clavaria), 51
botrytis (Clavaria), 7
Botrytis cinerea, germination of spores of, in sulphur compounds, 407
botrytoides (Clavaria), 8
Bromus, bacterial diseases of, 333
brunneola (Clavaria), 25
Burt, E. A. The North American species of Clavaria, with illustrations of the type specimens, 1

C

Calamaria, 104; *adspersa,* 115; *aequinoctialis,* 107; *alpina,* 122; *amazonica,* 125; *azorica,* 207; *Bolanderi,* 143; *Boryana,* 116; *Butleri,* 152; *coromandelina,* 109; *cubana,* 114; *Drummondii,* 125; *dubia,* 118; *Duriaei,* 209; *echinospora,* 154; *elatior,* 127; *flaccida,* 136; *Gardneriana,* 126; *Gunnii,* 124; *Hystrix,* 128; *humilior,* 134; *japonica,* 208; *Kirkii,* 123; *lacustris,* 186; *Lechleri,* 138; *longissima,* 119; *Malinverniana,* 113; *melanopoda,* 149; *melanospora,* 134; *Muelleri,* 127; *nigritiana,* 114; *Nuttallii,* 130; *olympica,* 118; *Perralderiana,* 121; *pygmaea,* 146; *riparia,* 181; *saccharata,* 179; *Savatieri,* 177; *Schweinfurthii,* 107; *setacea,* 110; *tegulensis,* 121; *tenuissima,* 117; *tripus,* 177; *triquetra,* 138; *Tuckermani,* 195; *Welwitschii,* 106
Calcium pentasulphide, toxicity of, 406
Calcium thiosulphate, toxicity of, 417
Calocera albipes, 65
Caulanthus, 247, 283; amplexicaulis, 285; **anceps,** 303; **californicus,** 299; **Cooperi,** 293; Coulteri, 296; crassicaulis, 292, var. glaber, 293; *crassicaulis* var. *major,* 291; **flavescens,** 301; *glaber,* 293; glaucus, 288; **Halli,** 290; *hastatus,* 282; **heterophyl-**

lus, 298; inflatus, 287; **lasiophyllus,** 303, var. **inalienus,** 306, var. **rigidus,** 307, var. **utahensis,** 307; Lemmonii, 297; **major** 291; pilosus, 289; *procerus,* 291, 302; *senilis,* 292; **simulans,** 295; **stenocarpus,** 300; **sulfureus,** 286
Cephaloceratodon, 104; *gymnocarpum,* 129; *hystrix,* 128
Cercospora Setariae, 341
Cereals, varieties of common, susceptible to foxtail organism, 343
cervicornis (Clavaria), 24
Chaetochloa geniculata, 340, 342; italica, 339, 342; lutescens, 333, 342
chionea (*Clavaria*), 29
Chlorocrambe, 245, 282; hastata, 282
cinerea (Clavaria), 40
cinereoides (Clavaria), 40
circinans (Clavaria), 27
cirrhata (Clavaria), 72
citriceps (Clavaria), 56
citrina (Clavaria), 61
citrino-fusca (Clavaria), 61
clara (Clavaria), 56
Clavaria, 1; abietina, 20; acris, 23; albida, 18; *albipes,* 65; amethystina, 41; amethystinoides, 42; arborea, 30; *Ardenia,* 59; argillacea, 53; asperula, 33; asperulans, 34; asperulospora, 60; asterella, 37; aurantio-cinnabarina, 43; aurea, 13; Berkeleyi, 61; bicolor, 61; *bicolor,* 67; biformis, 51; botrytis, 7; botrytoides, 8; brunneola, 25; cervicornis, 24; *chionea,* 29; cinerea, 40; cinereoides, 40; circinans, 27; cirrhata, 72; citriceps, 56; citrina, 61; citrino-fusca, 61; clara, 56; *clavata,* 55; compressa, 44; *compressa,* 62; conjuncta, 9; contorta, 60; corniculata, 38; coronata, 35; corynoides, 54; crassipes, 19; cristata, 31; cyanocephala, 16; *dealbata,* 72; decolor, 70; delicata, 71; delicia, 70; densa, 14; densissima, 14; divaricata, 37; driophylla, 62; *ericetorum,* 54; exigua, 42; fellea, 39; filipes, 53; fistulosa, 59; flaccida, 26; flava, 12; flavella, 57; flavobrunnescens, 22; flavula, 21; flavuloides, 28; foetida, 52; formosa, 11; *fragilis,* 48; fragrantissima, 28; fumigata, 15; fuscescens, 62; fusiformis, 44; gigantea, 68; gracilis, 28; gracillima, 54; grandis, 15; Herveyi, 39; holorubella, 10; inaequalis, 55; incurvata, 62; juncea, 60; Krombholzii, 32; Kunzei, 29; laeticolor, 57; lavendula, 47; lentofragilis, 37; lepidorhiza, 63; leucotephra, 21; ligula, 58; longicaulis, 17; Macouni, 45; misella, 49; molaris, 63; mucida, 50, var. Curtisii, 50; *muscoides,* 38; muscoides var. obtusa, 39; **mutans,** 31; myceliosa, 29; nebulosa, 47; nodulosperma, 34; obtusissima, 11; *ornatipes,* 65; pallescens, 46; Peckii, 38; *Peckii,* 67; Petersii, 35; pilipes, 59; **pilosa,** 46; pinicola, 25; pinophila, 36; pistillaris, 58; *pistillaris* var. *umbonata,* 58; platyclada, 45; polita, 63; pulchra, 57; pusilla, 27; pyxidata, 34; radiata, 64; rufipes, 33; rugosa, 32; scabra, 71; Schaefferi, 48; secunda, 19; *similis,* 38, 56; spathulata, 53; sphaerospora, 52; spiculospora, 17; stricta, 23; ***stricta* var. *fumida,* 23;** subcaespitosa, 30; *subcorticalis,* 66; subfalcata, 51; subtilis, 28; sulphurascens, 64; *tenax,* 67; tenuis, 49; testaceoflava var. testaceoviridis, 20; tetragona, 64; trichomorpha, 65; *trichopus,* 65; tricolor, 65; *truncata,* 69; tsugina, 24; *Typhuloides,* 69; vermicularis, 48; *vermiculata,* 48; vernalis, 55; *vestipes,* 67; xanthosperma, 18
clavata (*Clavaria*), 55
Cleome cuneifolia, 313
Colletotrichum Gossypii, germination of spores of, in sulphur compounds, 407
Colloidal sulphur: toxicity of, 410; hydrophilic, toxicity of, 410, chemistry of, 423; hydrophobic, toxicity of, 411
compressa (Clavaria), 44
compressa (*Clavaria*), 62
conjuncta (Clavaria), 9
contorta (Clavaria), 60
Coralloides amethystina, 41
corniculata (Clavaria), 38
coronata (Clavaria), 35
corynoides (Clavaria), 54
crassipes (Clavaria), 19
Craterellus pistillaris, 69
cristata (Clavaria), 31
cyanocephala (Clavaria), 16
cyanocephala (*Lachnocladium*), 16

D

Dactylis, bacterial diseases of, 333
dealbata (*Clavaria*), 72
dealbatum (Lachnocladium), 72
decolor (Clavaria), 70
delicata (Clavaria), 71
delicia (Clavaria), 70
delicia (*Lachnocladium*), 70
densa (Clavaria), 14
densissima (Clavaria), 14
divaricata (Clavaria), 37
driophylla (Clavaria), 62

E

ericetorum (*Clavaria*), 54
Erysimum retrofractum, 304
Euclisia amplexicaulis, 285
Euklisia longirostris, 310
exigua (Clavaria), 42

F

fellea (Clavaria), 39
filipes (Clavaria), 53
fistulosa (Clavaria), 59
flaccida (Clavaria), 26
flava (Clavaria), 12
flavella (Clavaria), 12
flavobrunnescens (Clavaria), 22
flavula (Clavaria), 21
flavuloides (Clavaria), 28
Flowers of sulphur, toxicity of, 408; finely ground, 409
foetida (Clavaria), 52
formosa (Clavaria), 11
Foxtail, a bacterial disease of, 333
Foxtail organism, diagnosis of, 383; hosts and extent of injury, 342; internal appearance and paths of infection of, 341; morphology of, 347; physiological reactions of, 380; precipitate production of, 376; toleration of acids by, 364
fragilis (*Clavaria*), 48
fragrantissima (Clavaria), 28
Fuller's scale, limitations of, 359
fumigata (Clavaria), 15
fuscescens (Clavaria), 62
fusiformis (Clavaria), 44

G

gigantea (*Acurtis*), 68
gigantea (Clavaria), 68
Gloeosporium venetum, germination of spores of, in sulphur compounds, 407
Glomerella cingulata, germination of spores of, in sulphur compounds, 407
gracilis (Clavaria), 28
gracillima (Clavaria), 54
Gramineae, bacterial diseases of, 333
grandis (Clavaria), 15
Guillenia, 283; *Cooperi*, 293; *flavescens*, 302; *Hookeri*, 302; *inaliena*, 306; *lasiophylla*, 304; *rigida*, 307; *rostrata*, 310

H

Herveyi (Clavaria), 39
Hesperidanthus, 259
Heterothrix, 259
Hibbardi (*Tremellodendron*), 67
holorubella (Clavaria), 10
Hordeum, bacterial diseases of, 333, 342
Hydrogen-ion concentration: in relation to growth, 376; methods of measuring, 356; relation of toxicity of sulphur compounds to, 418
Hydrogen sulphide, toxicity of, 404

I

inaequalis (Clavaria), 55
incurvata (Clavaria), 62
Isoetaceae, monograph of the, 79
Isoetella, 104; *Duriaei*, 209
Isoetes, 103; adspersa, 115, *220*; aequinoctialis, 107; *alata*, 137; alpina, 122, *222*; amazonica, 125; *ambigua*, 157; *Andina*, 138; azorica, 207, *232*; Bolanderi, 143, *228*, var. pygmaea, 146; *Bolanderi* var. *Parryi*, 143, var. *Sonnei*, 143; Boryana, 116, *220*; *brachyglossa*, 109; Braunii, 156, *230*, forma **robusta**, 173, var. **maritima**, 174; Brochoni, 156, *230*; Butleri, 152, *228*; *Butleri* var. *immaculata*, 152; *californica*, 143; *canadensis*, 184, var. *Robbinsii*, 184; *capsularis*, 109; *Chaboissaei*, 119; *Chapmani*, 136; coromandelina, 109, *218*; *cubana*, 113, *220*; *decipiens*, 119; *Delandei*, 128; *Dodgei*, 184, var. *Robbinsii*, 184; Drummondii, 125, *224*; dubia, 118; Duriaei, 209, *232*; Eatoni, 177, *230*; echinospora, 154, *230*, var. asiatica, 156; *echinospora* var. *Boottii*, 156, var. *Braunii*, 156, forma *Boottii*, 157, forma *robusta*, 173, var. *Brittonii*, 157, var. *Flettii*, 186, var. *maritima*, 174, var. *muricata*, 157, var. *robusta*, 173, var. *truncata*, 175; *edulis*, 208; elatior, 126; Engelmanni, 201, *232*, var. caroliniana, 207, *232*; *Engelmanni*, var. *fontana*, 201, var. *gracilis*, 201, var. *valida*, 201; flaccida, 136, *226*, var. **alata**, 137, *226*; *flaccida* var. *Chapmani*, 136, var. *rigida*, 136; **Flettii**, 186, *230*; foveolata, 200, *232*; Gardneriana, 126; *Gravesii*, 173; Gunnii, 124, *224*; *Harveyi*, 192; Heldreichii, 109; *heterospora*, 192; hieroglyphica, 194; histrix, 128, *224*, forma subinermis, 129; *histrix* forma *desquamata*, 129, var. *scutellata*, 129; *Hookeri*, 134; Howellii, 139, *228*, var. **minima**, 142; humilior, 134; japonica, 208; *Karstenii*, 138; Kirkii, 123, *222*; lacustris, 186, *230*; *lacustris*, 124, 192, var. *paupercula*, 189; Lechleri, 138; *leiospora*,

186; *ligustica,* 209; *lineolata,* 115; **lithophila,** 135, *226; longissima,* 120; *Macounii,* 174; macrospora, 192, *232,* forma **hieroglyphica**, 194, *232; macrospora* var. *heterospora,* 192; Malinverniana, 113, *218; maritima,* 174; Martii, 200; melanopoda, 149, *228; melanopoda* var. *californica,* 139, var. *pallida,* 149; melanospora, 134, *226;* mexicana, 147, *228;* minima, 142; *Montezumae,* 147; Muelleri 127; *muricata,* 157; natalensis, 210; neoguineensis, 211; nigritiana, 114; *nuda,* 139; Nuttallii, 130, *224; Nuttallii* var. *Orcuttii,* 132; occidentalis, 189, *230; occidentalis* var. *Piperi,* 190; olympica, 118; *opaca,* 130; Orcuttii, 132, *224;* **ovata,** 108, *218;* pauperacula, 190; Perralderiana, 121; phaeospora, 176; Piperi, 190; Pringlei, 185, *230;* pygmaea, 146; riparia, 181, *230,* var. canadensis, 184. *230;* saccharata, 179, *230; saccharata* var. *Palmeri,* 179, var. *reticulata,* 179; Savatieri, 177; Schweinfurthii, 107, *218;* setacea, 110, *218; setacea* var. *Delilei,* 119, var. *Perreymondii,* 115; *socia,* 138; *Stuartii,* 134; *Suksdorfii,* 130; *tasmanica,* 127; tegulensis, 121, *222;* tenuissima, 117, *220; tenuissima,* 127; *Tiguliana,* 121; *tridentata,* 209; tripus, 176; triquetra, 138; truncata, 175, *230;* Tuckermani, 195, *234; Tuckermani* var. *borealis,* 195, var. *Harveyi,* 192, var. *heterospora,* 192; Tuerckheimii, 147, *228; Underwoodi,* 139; *valida,* 177, 201, var. *Gravesii,* 173; velata, 119, *222,* forma **longissima,** 120, var. **Perralderiana,** 121, *222; velata* var. *longissima,* 120; *Viollaei,* 117; Welwitschii, 106; Wormaldii, 208

J

juncea (Clavaria), 60

K

Krombholzii (Clavaria), 31
Kunzei (Clavaria), 29

L

Lachnocladium bicolor, 65; *cyanocephala,* 16; dealbatum, 72; *delicia,* 70; **ornatipes,** 65; **subcorticale,** 66; **vestipes,** 67
laeticolor (Clavaria), 57
lavendula (Clavaria), 47
lentofragilis (Clavaria), 37
lepidorhiza (Clavaria), 63
leucotephra (Clavaria), 21
ligula (Clavaria), 58
Lime sulphur, toxicity of, 406, 414
longicaulis (Clavaria), 17

M

Macouni (Clavaria), 45
Macropodium, 261; *laciniatum,* 272
Macrosporium sarcinaeforme, germination of spores of, in sulphur compounds, 408
Marsilea, 104
Media, growth of foxtail organism on various, 361
Merisma tenax, 67
misella (Clavaria), 49
molaris (Clavaria), 63
Monograph of the Isoetaceae, 79
Monographic study of Thelypodium and its immediate allies, A, 233
mucida (Clavaria), 50, var. Curtisii, 50
muscoides var. obtusa (Clavaria), 39
muscoides (Clavaria), 38
mutans (Clavaria), 31
myceliosa (Clavaria), 29

N

nebulosa (Clavaria), 47
nodulosperma (Clavaria), 34
North American species of Clavaria, with illustrations of the type specimens, The, 1
Nymphaea, a new hybrid, 325
Nymphaea daubeniana, 325; flavo-virens, 325; gracilis, 325, *330;* ovalifolia, 325, *328;* "Panama Pacific," 325; **"Mrs. G. H. Pring,"** 325, *328, 330, 332,* var. **marmorata,** 327; "Stella Gurney," 325; "William Stone," 325; "Mrs. C. W. Ward," 325; "Mrs. Edwards Whitaker," 325, *328;* "Mrs. Woodrow Wilson," var. gigantea, 325

O

obtusissima (Clavaria), 11
ornatipes (Clavaria), 65
ornatipes (Lachnocladium), 65
Oryza, bacterial disease of, 339, 342
Oxygen, influence of, on toxicity of sulphur, 421

P

Pachypodium, 261; *ciliatum,* 272; *integrifolium,* 277, 279; *laciniatum,* 272; *sagittatum,* 267

pallescens (Clavaria), 46
Payson, E. B. A monographic study of Thelypodium and its immediate allies, 233
Peckii (Clavaria), 38
Peckii (*Clavaria*), 67
Petersii (Clavaria), 35
Pfeiffer, Norma E. Monograph of the Isoetaceae, 79
Phleum, bacterial diseases of, 333, 342
Phomopsis Sojae, germination of spores of, in sulphur compounds, 408
pilipes (*Clavaria,*) 59
pilosa (Clavaria), 46
pinicola (Clavaria), 25
pinophila (Clavaria), 36
Piricularia, 341
Pistillaria **Typhuloides**, 69
pistillaris (Clavaria), 58
pistillaris umbonata (*Clavaria*), 58
pistillaris (Craterellus), 69
platyclada (Clavaria), 45
Pleurophragma, 241, 261; *gracilipes*, 277; *integrifolium*, 277, 279; *platypodum*, 276
Poa, bacterial diseases of, 333, 342
polita (Clavaria), 63
Pring, George H. A new hybrid nymphaea, 325
Pseudomonas Avenae, 337; **albopre-cipitans**, 383; Tritici, 339; vascularum, 336
Pterula tenax, 67
pulchra (Clavaria), 57
pusilla (Clavaria), 27
pyxidata (Clavaria), 34

R

radiata (Clavaria), 64
Ramaria amethystina, 41; *cristata*, 31
Rosen, H. R. A bacterial disease of foxtail (Chaetochloa lutescens), 333
rufipes (Clavaria), 33
rugosa (Clavaria), 32

S

Saccharum, bacterial diseases of, 333
scabra (Clavaria), 1
Schaefferi (Clavaria), 48
Sclerotinia cinerea, germination of spores of, in sulphur compounds, 407
Secale, bacterial diseases of, 333, 342
secunda (Clavaria), 19
Setaria, bacterial diseases of, 333
similis (*Clavaria*), 38, 56
Sisymbrium erysimioides, 258
Sisymbrium, 258; *acutangulum*, 306; *acuticarpum*, 306; *deflexum*, 304, 307, var. *xerophilum*, 304; *lasiophyllum*, 304; *reflexum*, 304
spathulata (Clavaria), 53
sphaerospora (Clavaria), 52
spiculospora (Clavaria), 17
Stanfordia, 283; *californica*, 299
Stanleya *amplexifolia*, 312; confertiflora, 244; *gracilis*, 313
Stanleyella, 256, 315; Wrightii, 315, var. **tenellum**, 317
Streptanthella, 255, 309; longirostris, 310
Streptanthus, 283; *californicus*, 299; campestris, 286; *Coulteri*, 296; *crassicaulis*, 292; *flavescens*, 301; *heterophyllus*, 296; *Howellii*, 265; *inflatus*, 287; *longirostris*, 310; *Parryi*, 297; *procerus*, 301; *sagittatus*, 267
stricta (Clavaria), 23
stricta var. *fumida* (*Clavaria*), 23
subcaespitosa (Clavaria), 30
subcorticale (Lachnocladium), 67
subcorticalis (*Clavaria*), 66
subfalcata (Clavaria), 51
subtilis (Clavaria), 28
Subularia, 104
Sulphur, The toxic property of, 403
Sulphur dioxide, toxicity of, 404, 421
Sulphur trioxide, toxicity of, 405, 421
sulphurascens (Clavaria), 64
Sulphuric acid, toxicity of, 405, 421
Sulphurous acid, toxicity of, 404

T

Temperature: effect of, on growth of foxtail organism, 380; relation of, to infection, 346
tenax (*Clavaria*), 67
tenax (*Merisma*), 67
tenax (*Pterula*), 67
tenax (Tremellodendron), 67
tenuis (Clavaria), 49
testaceoflava var. testaceoviridis (Clavaria), 20
tetragona (Clavaria), 64
Thelypodiopsis, 242; *aureum*, 244; *elegans*, 243
Thelypodium, 260; affine, 278; *ambiguum*, 243; *amplifolium*, 267; brachycarpum, 263; *brachycarpum*, 264: *Cooperi*, 293; **crispum**, 264; *deserti*, 294; eucosum, 262; *flavescens*, 301, 302; flexuosum, 271; *gracilipes*, 277; *Greenei*, 302; *Hookeri*, 302; Howellii, 265; integrifolium, 277; *integrifolium*, 276, 277, 278, 279, 281, var. *gracilipes*, 277; laciniatum, 272, var. **milleflorum**, 274, var. **streptanthoides**, 274; *laciniatum*, 274; *lasiophyllum*, 304, 307, var. *inalienum*, 306,

var. *rigidum*, 307, forma *xerophilum*, 304; *Lemmoni*, 303; *leptosepalum*, 272; lilacinum, 279, var. **subumbellatum**, 281; *macropetalum*, 268; *milleflorum*, 274; *neglectum*, 272, 304; *Nuttalli*, 262, 267; ovalifolium, 266; *Palmeri*, 266; *paniculatum*, 268; rhomboideum, 276, var. **gracilipes**, 277; *rigidum*, 307; sagittatum, 267, var. **crassicarpum**, 269; *sagittatum*, 268, 269; *simplex*, 265; stenopetalum, 271; *streptanthoides*, 274; *torulosum*, 268, 269; *utahense*, 307; vernale, 267; *Wrightii*, 315, var. *tenellum*, 317

Thelypodium, 283

Tremellodendron *Hibbardi*, 67; **tenax**, 67

trichomorpha (Clavaria), 65

trichopus (*Clavaria*), 65

tricolor (Clavaria), 65

Triticum, bacterial diseases of, 333, 342

truncata (*Clavaria*), 69

tsugina (Clavaria), 24

Turritis lasiophylla, 303

Typhuloides (*Clavaria*), 69

Typhuloides (Pistillaria), 69

V

vermicularis (Clavaria), 48

vermiculata (*Clavaria*), 48

vernalis (Clavaria), 65

vestipes (*Clavaria*), 67

vestipes (Lachnocladium), 67

Volatile products of sulphur, toxicity of, 419

W

Warea, 256, 311; amplexifolia, 312; *amplexifolia*, 312; Carteri, 314; cuneifolia, 313; *cuneifolia*, 314; sessilifolia, 312

Water, influence of, on sulphur compounds, 423

X

xanthosperma (Clavaria), 18

Y

Young, H. C. The toxic property of sulphur, 403

Z

Zea, bacterial diseases of, 333, 342